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IN SITU SEISMIC INVESTIGATION OF BLACK BUTTE DAM

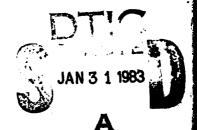
by

José L. Llopis and Ronald E. Wahl

Geotechnical Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

December 1982 Final Report

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Prepared for U. S. Army Engineer District, Sacramento Sacramento, Calif. 95814

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An in situ seismic investigation consisting of surface refraction, surface vibratory, downhole, and crosshole seismic tests was conducted at Black Butte Dam located near Orland, Calif. Compression-, shear-, and Rayleigh-wave (P-, S-, and R-wave) velocities as a function of depth were determined for the Black Butte Dam and underlying foundation materials.

Kesults of the investigation indicated that P-wave velocities in the dam's core exhibited values of 2150, 5050, and 3050 fps with (Continued)

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20. Abstract (Continued).

increasing depth. The random-fill section indicated velocities of 1825 and 3225 fps. The foundation materials exhibited velocities of 1500, 4400, 6775, and 9850 fps; the first two foundation zones correlated with alluvium while the latter two were representative of the Black Butte Series and Chico Formation, respectively. Materials on the right abutment had velocities of 1225, 3500, and 9825 fps corresponding to slope wash, Tehama Formation, and basalt flows, respectively, while materials on the left abutment were determined to have velocities of 2375 and 8225 fps representative of slope wash and basalt, respectively.

The S-wave velocity profile showed that the dam's core had velocities of 875, 650, and 975 fps with increasing depth. The random-fill section of the dam had velocities of 1100 and 1675 fps. Foundation materials had velocities of 675, 1350, and 1800 fps with the first two velocities representative of alluvium and the third velocity corresponding to the Black Butte Series. R-wave velocities on the right abutment ranged from about 640 to 1125 fps from near surface to a 37-ft depth.

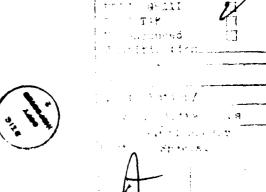
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PREFACE

An in situ seismic investigation at Black Butte Dam was authorized by the U. S. Army Engineer District, Sacramento, under IAO Nos. SPKED-F-80-23 and SPKED-F-82-1, dated 3 April 1980 and 14 October 1981, respectively.

The field investigation was performed during the periods 12-15 May 1980 and 18-22 May 1982. Messrs. Ronald E. Wahl, José L. Lloris, Donald E. Yule, Donald H. Douglas, Rodney N. Walters, and Michael K. Sharp, and LT Stephen G. Sanders of the Field Investigations Group, Earthquake Engineering and Geophysics Division (EEGD), Geotechnical Laboratory (GL), and Mr. Monroe B. Savage of the Instrumentation Services Division (ISD), of the U. S. Army Engineer Waterways Experiment Station (WES), were members of the field parties who carried out this project. The analysis phase of this study was performed by Messrs. Wahl and Llopis under the general supervision of Dr. Arley G. Franklin, Chief, EEGD, and Dr. William F. Marcuson III, Chief, GL. This report was written by Messrs. Llopis and Wahl.

COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE, were Commanders and Directors of WES during the performance of this investigation and the preparation of this report. Mr. Fred R. Brown was Technical Director.



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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	Ву	To Obtain
feet	0.3048	metres
miles (U. S. statute)	1.609347	kilometres
pounds (force)	4.448222	newtons
pounds (mass)	0.4535924	kilograms

IN SITU SEISMIC INVESTIGATION OF BLACK BUTTE DAM

PART I: INTRODUCTION

Background, Purpose, and Scope of Study

- 1. Current computerized seismic wave propagation analysis procedures for earth dams and foundations require that values of compressionand shear-wave (P- and S-wave) propagation velocities as a function of depth be determined. These seismic velocities are used in conjunction with conventional field sampling and laboratory testing to provide soil property information for a dynamic analysis of the dam and its foundation.
- 2. A geophysical investigation was conducted at Black Butte Dam, which is located on Stony Creek approximately nine miles* west of the town of Orland, Calif., as shown in Figure 1. The investigation was performed to determine P- and S-wave velocities as a function of depth within the dam and its underlying foundation materials. A suite of seismic test methods was used in order to determine an optimal P- and S-wave velocity zonation of the dam and foundation for use in a dynamic analysis.

Site Description

3. The Black Butte Dam is a zoned earth-fill structure with a crest length of 2970 ft, a maximum width of about 700 ft, and a maximum height of 150 ft; construction was completed in 1963. The zones consist of a central impervious core and a random-fill shell. The impervious core trench was founded on rock (basalt) on the abutments and mudstone in the valley section. Depths of excavation for the core trench ranged from approximately 1 to 60 ft. The foundation for the embankment consists of the Chico Formation, the Black Butte Series, and alluvium.

^{*} A table for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

- 4. The Chico Formation consists of sandstone, sandy shales, conglomerates, and a minor amount of limestone. The sediments overlying the Chico Formation are referred to as the Black Butte Series. The basal member is a conglomerate with an average thickness of 25 ft; it is overlain by materials grading upward from a clayey sandstone through a pseudosandstone (i.e., has the appearance of fine-grained sandstone, but is composed of clay to an arenaceous claystone). This material has been grouped under the general heading of mudstone.*
- 5. The majority of the alluvium upon which the dam is founded consists chiefly of floodplain and stream deposits. The floodplain deposits consist of lenticular deposits of clay, silt, sand, and gravel. These deposits are gray in color, unconsolidated, and have been deposited in such a manner that fines predominately occupy the upper limits with the gravels largely confined to the lower two-thirds. The vertical thickness of this deposit averages 8 ft. The Recent stream deposits are chiefly rounded to subrounded rock fragments (gravel) and are composed of volcanics with minor amounts of diorite, quartzite, schists, and chert. These deposits are porous, loose, and are 17 to 20 ft in vertical thickness.* A plan view of the dam is shown in Figure 2. Transverse and longitudinal cross sections are presented in Figure 3.

Test Program

6. After a preliminary geophysical test program had been planned by personnel of the U. S. Army Engineer District, Sacramento, it was submitted to the U. S. Army Engineer Waterways Experiment Station (WES) for review. Pertinent information relative to the design and construction of the embankment was provided to aid in that review. The finalized test program consisted of seismic refraction, crosshole, downhole, and surface vibratory tests which would provide the geophysical data necessary to complete an analysis of the dam's response to earthquake loadings.

^{*} Design Memorandum No. 4, Biack Butte Project, Stony Creek, Calif., Dam and Appurtenances, Appendix A, 1 January 1959, U. S. Army Engineer District, CE, Sacramento, Calif.

The locations of the tests performed during this investigation are shown in Figure 2. The average pool elevation while conducting surface refraction and vibratory tests was 459 ft (12-15 May 1980). During the performance of crosshole and downhole tests, the average pool elevation was 461 ft (18-22 May 1982).

- 7. Seismic refraction tests. Surface seismic refraction tests were conducted to determine P-wave velocities, layering (depth to interfaces having contrasting velocities), and anomalous conditions (if any). These tests consisted of four lines, designated R-1 through R-4 which were located and oriented as shown in Figure 2. Forward and reverse traverses were run for each line. Line R-1 was run along the toe of the dam and had a length of 625 ft. Line R-2 was located on the dam crest and was 900 ft long. Line R-3 was run on the right abutment and had a length of 500 ft. Line R-4 was located on the left abutment and had a length of 200 ft.
- 8. Surface vibratory tests. Ten vibratory lines, designated as V-1 through V-10, were run as shown in the test layout (Figure 2). These tests were conducted to determine Rayleigh-wave (R-wave) velocities, which are similar in magnitude to S-wave velocities, as a function of depth. Lines V-1 through V-4 were located on the dam crest while lines V-5 through V-8 were located on the toe. Lines V-9 and V-10 were run on the right abutment. All the vibratory lines were 200 ft in length.
- 9. <u>Crosshole tests</u>. Crosshole tests were conducted in three borehole sets (AB, CD, and EF) with each set consisting of two borings. Boreholes in each set were spaced approximately 10 ft apart at the locations shown in Figure 2.
- 10. The purpose of the crosshole investigation was to determine horizontal P- and S-wave velocities as a function of depth. One advantage of crosshole testing as opposed to surface seismic refraction is its ability to detect lower velocity layers underlying or sandwiched between layers of higher velocity. The crosshole technique is therefore considered to be inherently more definitive and accurate than the surface refraction test but has the shortcoming of requiring boreholes and

not being able to cover as much areal extent; thus the techniques are used in a complementary manner.

- 11. Borehole set AB was approximately 45 ft deep and was located on the center line of the crest near sta 21+00. These borings were used for obtaining velocities of the impervious core. Borehole set CD was approximately 135 ft deep and located 32 ft below the crest of the dam on the downstream face near sta 21+00; these borings were designed to obtain velocities of the pervious zone, alluvium, and Black Butte Series (i.e., the foundation materials). Borehole set EF was approximately 95 ft deep and located on the downstream toe near sta 21+00; these torings passed through the alluvium and into the Black Butte Series.
- 12. All borings for the crosshole tests were drilled 8 in. in diameter and cased with 4-in. ID polyvinyl chloride (PVC) pipe by WES personnel. The annular space between the casing and walls of the borings was grouted with a mixture of portland cement, bentonite, and water, which, after setting up, had approximately the consistency of soil. A borehole deviation survey was conducted to determine precise vertical alignment because accurate reduction of data from the crosshole tests requires knowledge of the drift of each borehole so that a straight-line distance between boreholes at each test depth can be established. Since distances and corresponding arrival times were known for each test elevation, an analysis of the crosshole data obtained from each of the three sets was made with the aid of a computer program developed at WES.*
- 13. <u>Downhole tests</u>. Downhole P- and S-wave tests were conducted to complement surface seismic refraction and crosshole tests thereby increasing overall confidence in data obtained. Downhole P- and S-wave tests were conducted in borings A, C, and E at 5-ft-depth intervals with the source located 5 to 9 ft from the mouth of the borehole. In addition to the determination of P- and S-wave velocities, the downhole test has the ability to detect inversion layers. However, certain limitations must be recognized:

^{*} Butler, D. K., Skoglund, G. R., and Landers, G. B. 1978. "CROSSHOLE: An Interpretative Computer Code for Crosshole Seismic Test Results, Documentation, and Examples," Miscellaneous Paper S-78-8, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

- a. Lower limits of measurable velocity are inherently established by the velocity of the casing or grout which can act as a wave guide for the vertically traveling seismic waves.
- b. Accuracy of incremental velocities is directly related to the preciseness of timing control available on the seismograph. In high velocity materials, incremental time differences could be on the order of 1 or 2 msec. Therefore, an error of 0.5 msec in a distance of 10 ft or less would be appreciable. In view of these limitations, the downhole test must be used with discretion.

Equipment and Test Procedures

- 14. <u>Seismographs</u>. Two different types of seismographs were utilised for recording surface refraction, surface vibratory, crosshole, and downhole test data. Refraction lines R-1 and R-3, and all surface vibratory lines were performed using a portable, battery-powered, 24-channel seismograph, and an oscillograph. Refraction lines R-2 and R-4, crosshole, and downhole tests were conducted with a portable, battery-powered, 12-channel seismograph which had data-enhancement capability.
- 15. Geophones. For seismic refraction and surface vibratory tests, material response was detected by vertically oriented geophones. For crosshole and downhole tests, the material response was monitored by a triaxial array of geophones (two mounted horizontally at 90 deg to each other, and one vertically oriented) housed in one container.
- 16. Energy sources. For seismic refraction lines R-1 through R-3 the seismic energy source was 2 to 5 1b of two-component explosive charges with the amount of explosives used being dependent on the length and location of the line. Charges were buried between 3 and 5 ft dependent on the location of the line. For refraction line R-4, the seismic source was generated by applying sledgehammer blows to a steel plate seated on the ground surface.
- 17. The energy source for the surface vibratory lines was a 4000-1b force (peak) electrohydraulic vibrator with a 10- to 300-Hz frequency range.

- 18. For crosshole seismic tests, a downhole vibrator was used as a generator of vertically polarized shear (SV) waves. Exploding bridgewire detonators were used as a P-wave source.
- 19. The energy source for the determination of P-wave velocities for the downhole test consisted of striking a steel plate, seated on the ground, with a sledgehammer. S-waves for the downhole S-wave test were generated by alternately striking each end of a wooden plank lying on the ground with a sledgehammer.
- 20. All phases of the geophysical test program with the exception of the surface vibratory and crosshole S-wave tests were conducted in accordance with procedures outlined in Chapter 3 of EM 1110-1-1802, "Geophysical Exploration," dated 31 May 1979. In this manual, a detailed description of each test technique employed is presented along with pertinent background information. The surface vibratory test procedure consisted of positioning the vibrator at a selected location and placing the geophones in a straight line (starting at and extending away from the vibrator) at selected intervals along the surface of the ground. The vibrator was then operated at discrete selected frequencies with the surface R-wave being monitored by the transducers (geophone nearest the vibrator served as zero time). The time lag, referenced to the zero time geophone, is determined and plotted versus the respective distances that the geophones were from the vibrator. The R-wave velocity for the source frequency is determined from the slope of the line obtained in the plot. When the frequency and R-wave velocity are known, a corresponding wavelength can be computed by dividing the velocity by the frequency. Wave velocities thus derived are considered to be average values* for an

^{*} R-wave velocities that are determined near a high velocity contrast interface, such as a soil-rock boundary, will probably be influenced by both the higher and lower velocity materials and thus provide weighted average velocities dependent on the physical properties of two layers.

effective depth of one-hali the wavelength. As mentioned previously, R-wave velocities are numerically close to S-wave velocities. For the range of Poisson's ratios commonly found in soil materials, the maximum difference between R- and S-wave velocities is less than 10 percent.*

21. The crosshole S-wave test differed from that described in EM 1110-1-1802 in that instead of using a surface-mounted vibrator as a seismic source, a downhole vibrator was employed. The procedure consisted of lowering the vibrator in the borehole to a selected test elevation and clamping the vibrator firmly to the sidewalls of the PVC casing by means of an inflatable rubber bladder. When the vibrator was in position, the operator swept the oscillator through a range of frequencies (50- to 500-Hz) and selected one that propagated well (one with a high amplitude) through the transmitting medium. The time required for the transmitted signal to reach the receiver geophone was recorded with a seismograph with enhancement capabilities and the corresponding S-wave velocity determined.

^{*} Ballard, R. F., Jr. 1964. "Determination of Soil Shear Moduli at Depths by In Situ Vibratory Techniques," Miscellaneous Paper 4-691, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

PART II: TEST RESULTS

Surface Seismic Refraction Tests

- 22. Basic data acquired from seismic refraction tests are conventionally displayed in time-distance plots. The data from lines R-1 through R-4 are shown in Figures 4-7, respectively.
- 23. Seismic refraction line R-1 was located on the toe of the dam between sta 19+00 and 25+25. Four P-wave velocity zones were determined as shown in Figure 4.* The first zone extended to depths of 6 and 16 ft and had an average velocity of 2150 fps. The underlying second zone was encountered to depths of 23 and 42 ft and had a true velocity of 4750 fps. Zone 3 had a true velocity of 6750 fps and ranged from 110 to 115 ft in depth where Zone 4 was encountered with a true velocity of 9850 fps.
- 24. Seismic refraction line R-2 was run on the crest of the dam approximately between sta 19+00 and 28+00. Three P-wave velocity zones were indicated as shown in Figure 5. The first zone had an average velocity of 1625 fps and extended to depths between 10 and 40 ft. The underlying zone had a true velocity of 2950 fps and ranged between 132 and 136 ft in depth where Zone 3 was encountered with a true velocity of 6875 fps.
- 25. Seismic refraction line R-3 was located on the right abutment between the outlet channel and downstream toe (sta 12+00 to 17+00) and was oriented in a southeast-northwest direction. Three P-wave velocity zones were detected as shown in Figure 6. The first zone had an average velocity of 1225 fps corresponding to the overburden and ranged from 5 to 11 ft in thickness. Zone 2, corresponding to the Tehama Formation (poorly consolidated, fluvially deposited pebbles, sand, silts, and clays) extended to depths ranging from 18 ft on the northwestern end of the line to 58 ft on the southeastern end and had a true velocity of 3500 fps.

^{*} All velocities reported are assumed, based on timing resolution and judgment, to have an accuracy of ± 12.5 fps.

Below the above zones, layer 3, which corresponds to the basalt layer, had a true velocity of 9825 fps.

26. The time-distance plot for seismic line R-4 which was located on the dam's left abutment and oriented in an east-west direction is presented in Figure 7. Two velocity zones were determined. The first zone which corresponds to talus (basalt rubble) deposits had an average velocity of 2375 fps with a thickness varying from 34 ft on the western end of the line to 15 ft on the eastern end. The underlying material, basalt, had a true velocity of 8225 fps.

Downhole P-Wave Tests

- 27. Downhole test results are presented in conventional time versus slant distance (slant distance is nearly equal to depth) plots. Figures 8-10 show the results of downhole P-wave tests conducted at 5-ft-depth intervals in borings A, C, and E, respectively.
- 28. Figure 8 presents the data collected from the downhole test conducted in boring A, crest of dam, which was 45 ft deep. Two velocity zones were indicated which are tabulated as follows:

Approximate		
	Depth to Top	
Zone	of Interface ft	<u>Velocity</u> , fps
1	0	2165
2	25	2750

29. Figure 9 presents the data acquired from the downhole P-wave test in boring C, downstream face, which was 135 ft deep. Four velocity zones were determined as follows:

	Approximate	
	Depth to Top	
Zone	of Interface, ft	Velocity, fps
1	0	1900
2	10	3300
3	105	4000
4	120	6675

30. Figure 10 presents the data collected from the downhole P-wave test conducted in hole E, located on the downstream toe of the dam, which was 95 ft deep. The results indicated three velocity zones tabulated as follows:

	Approximate Depth to Top	
Zone	of Interface, ft	Velocity, fps
1	0	1300
2	12	4375
3	33	7075

Downhole S-Wave Tests

- 31. Data obtained from downhole S-wave tests are conventionally shown in arrival time versus slant distance plots. Slant distance is almost equal to depth. The results of the downhole S-wave tests conducted in boreholes A, C, and E are presented in Figures 11-13, respectively.
- 32. Only one velocity zone was detected from the downhole S-wave test conducted in boring A which was located on the crest, as shown in Figure 11. The velocity of this zone was determined to be 925 fps.
- 33. Figure 12 presents data acquired from the downhole S-wave test conducted in boring C, downstream slope. Two S-wave velocity zones were interpreted as follows:

	Approximate	
	Depth to Top	
Zone	of Interface, ft	Velocity, fps
1	0	1000
2	20	1920

34. Figure 13 presents results from the downhole S-wave test conducted in boring E located on the downstream toe. Two velocity zones were indicated as follows:

	Approximate Depth to Top	
Zone	of Interface, ft	Velocity, fps
1	0	600
2	12	1825

Surface Vibratory Tests

- 35. The results from the ten surface vibratory lines (V-1 through V-10) are shown as R-wave velocity versus depth plots which are presented in Figures 14-18. A best-fit curve was drawn through the points in each plot to obtain the velocity profile.
- 36. Figure 14 presents the R-wave velocity versus depth data for lines V-1 and V-2 which were run on the paved service road on the crest of the dam approximately between sta 18+00 and 22+00. The velocities ranged between 700 and 950 fps and were nearly constant at about 900 fps between depths of 5 and 10 ft below which the velocity decreased quite rapidly to about 700 to 750 fps. Below 15 ft, the velocity gradually increased to 950 fps to a depth of 60 ft. The higher velocities encountered near the surface are probably due to a higher shear modulus associated with the pavement and subgrade materials.
- 37. Figure 15 presents the R-wave velocity versus depth plot for vibratory lines V-3 and V-4 which were run on the crest of the dam between sta 24+00 and 28+00. The best-fit curve for these lines showed a decrease in velocity from 830 fps at 6 ft to 700 fps at 9 ft. From 9 to 27 ft, the velocity remained fairly constant at 700 fps. Below 27 ft, there is a gradual increase to about 900 fps at a depth of 55 ft.
- 38. Figure 16 presents the R-wave velocity versus depth for lines V-5 and V-6 which were located on the toe of the dam between sta 24+00 and 28+00. The best-fit curve showed a nearly constant velocity of about 700 fps to a depth of 10 ft at which point the velocity increased almost linearly with depth to 1000 fps at 27 ft.
- 39. Figure 17 presents the results from vibratory lines V-7 and V-8 run on the toe of the dam approximately between sta 19+00 and 23+00. The best-fit curve indicated a decrease in velocity from 800 to 750 fps in the 6 to 8-ft-depth range. Below 8 ft, the velocity increased almost linearly to 1000 fps at a depth of 27 ft.
- 40. Figure 18 presents results from vibratory lines V-9 and V-10 which were run on the right abutment of the dam between sta 13+00 and 17+00. Two best-fit lines were drawn for the data. Data from line

V-9 exhibited a linear increase in velocity with depth ranging from 640 fps at approximately 6 ft to 950 fps at about 33 ft. Velocities from lines V-9 and V-10 coincided between depths of 6 and 10 ft and appeared to correlate with the overburden materials. At a depth of approximately 10 ft, the velocity from line V-10 indicated a sharp increase to about 750 fps and then began to increase almost linearly with depth to 1125 fps at 37 ft. The depth to the higher velocity basalt is less below line V-10 than line V-9; therefore, a higher R-wave velocity is exhibited by line V-10 because of the R-wave averaging characterisites near a high-velocity contrast interface.

Crosshole Tests

- 41. The calculated true P- and S-wave velocities as determined by the crosshole computer program at each test elevation for the three crosshole sets are presented in Figure 19. As noted, test elevations were at 5-ft intervals except for crosshole set EF (toe) where no data were obtained from the S-wave test in the upper 10 ft. Also shown in Figure 19 are P- and S-wave velocity zones and depths to interfaces as established by the computer program and judgment.
- 42. The P-wave velocities for crosshole set AB representative of the core material indicated three velocity zones as follows:

Zone	Depth to Top of Interface, ft	Velocity, fps
1	0	2950
2	27	5050
3	33	3450

43. The S-wave velocity zones for crosshole set AB indicated three zones as follows:

Zone	Depth to Top of Interface, ft	Velocity, fps
1	0	825
2	13	525
3	23	1050

44. The P-wave velocity zones for crosshole set CD representative of the pervious zone and foundation materials are as follows:

Zone	Depth to Top of Interface, ft	Velocity, fps
1	0	1750
2	10	3150
3	113	4600
4	121	6550

45. The S-wave velocity zones for crosshole set CD are as follows:

a -	Depth to Top	Walashan Fas
Zone	of Interface, ft	Velocity, fps
1	0	1200
2	36	1550
3	114	1400
4	121	1700

46. The P-wave velocity zones for crosshole set EF representative of the dam's foundation materials are as follows:

	Depth to Top	
Zone	of Interface, ft	Velocity, fps
1	0	1275
2	10	4375
3	24	6875

47. The S-wave velocity zones for crosshole set EF are as follows:

Zone	Depth to Tor of Interface, ft	Velocity, fps
1	0	
2	15	1175
3	27	1850

Data Consolidation

48. In order to make a meaningful interpretation of the data acquired at various locations along the dam using the four different geophysical techniques, it is convenient to present the data in

composite form so that a zonal interpretation can be developed using all the available data. Such composites were prepared for P- and S-wave tests conducted in the vicinity of the cross section near 21+00 and are presented in Figures 20 and 21, respectively.

- 49. As shown in Figure 20, three zones of the dam were tested: core, random (pervious), and foundation beneath and at the toe of the dam. Results determined from seismic refraction, downhole, and crosshole tests are presented for the core and foundation materials at the toe, while downhole and crosshole results are depicted for the random zone. Comparison of the results from each test for a specific zone are generally in good agreement on velocities and depths to interfaces.
- 50. As depicted in the S-wave composite (Figure 21) tests were conducted in the same three zones shown in the P-wave composite. Results from crosshole, downhole, and surface vibratory tests are presented for the dam core and foundation materials at the toe. Results from the downhole and crosshole tests are presented for the random zone and foundation material beneath the dam. Velocities and depths to interfaces differ somewhat due to varying limitations between test techniques.

PART III: INTERPRETATION

P-Wave Velocities

51. The P-wave velocity composite (Figure 20) was analyzed and a zonal interpretation made for sta 21+00 using weighted averaging and judgment based on data quality and the limitations and advantages of each test performed. Since the borings on the crest did not penetrate the foundation materials, thus preventing the acquisition of data from downhole and crosshole tests, two approaches were used to present values for use in this region for the seismic wave propagation analysis. The first approach does not involve the extrapolation or interpolation of velocities beyond areas in which measurements were made, and is presented in Figure 22. The zoning through the core and underlying foundation revealed four velocity zones. The first zone had a velocity of 2150 fps and extended to a depth of about 25 ft. The second zone had a velocity of 5050 fps with a thickness of 8 ft. It will be noted that both the seismic refraction and downhole P-wave tests failed to discern this layer; however, it was detected by the crosshole P-wave test. Even though only one out of three tests distinguished this faster layer, it was felt that it should be reported since the boring logs indicated the highest blow counts occurred in this zone. Underlying the above zones was a 3050-fps layer which extended to approximately 150 ft (the damfoundation contact). The fourth zone corresponding to the Black Butte Series had a velocity of 6875 fps to undetermined depths. Four velocity zones were interpreted for the random material. The first zone had a velocity of 1825 fps and extended to a depth of 10 ft. The underlying second zone extended to a depth of about 110 ft with a velocity of 3225 fps. Underlying the above layers was a third zone having a velocity of 4300 fps which corresponded with the alluvium. At a depth of about 122 ft, the Black Butte Series was encountered with a velocity of 6625 fps to 135 ft. The tests conducted at the downstream toe of the dam revealed four P-wave velocity zones for the foundation material. The near-surface layer exhibited a velocity of 1500 fps and had a

thickness of 10 ft. The second zone had a velocity of 4500 fps and extended to a depth of 27 ft. The first two zones correlated with the alluvium. The Black Butte Series was encountered at a depth of 27 ft and had a velocity of 6900 fps. The seismic refraction line exhibited a fourth zone having a 9850 fps velocity at a depth of about 111 ft. It is possible that this zone corresponds to the Chico Formation.

52. The second approach for interpreting P-wave data was to assign zonal velocities according to constructed zones of the dam and foundation layering this involves some interpolation and extrapolation based on the principle that with other things being equal seismic wave velocities increase with effective stress. The results of this method are presented in Figure 23 for the cross section through sta 21+00. Three velocity zones were interpreted for the core (Figure 23). The upper 25 ft of core material had a velocity of 2150 fps while the underlying second zone had a velocity of 5050 fps. The lateral extent of the second layer cannot be predicted. The core, from a depth of 33 ft to the dam-foundation contact, had a velocity of 3050 fps. The random zone exhibited two velocity zones. The upper 10 ft of random zone material had a velocity of 1825 fps. The rest of the random zone was assigned a velocity of 3225 fps. Results of testing in the foundation materials yielded four velocity zones. The first zone which was encountered only at the downstream toe had a thickness of 10 ft and a velocity of 1500 fps. The second zone exhibited a velocity of 4400 fps and correlated with the alluvial sand and gravel layer. The third zone, indicative of the Black Butte Series, had a velocity of 6775 fps. The thickness (about 84 ft) of the Black Butte Series was measured only at the toe of the dam. Underlying the Black Butte Series, the Chico Formation was encountered with a corresponding velocity of 9850 fps at a depth of about 111 ft.

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S-Wave Velocities

53. S-wave zonal interpretations were made in the same manner as employed for P-wave interpretations previously discussed. Figure 24

presents the S-wave zonal velocity interpretation through the cross section at sta 21+00. Three zones were determined for the core. The first zone extended to a depth of 12 ft and had a velocity of 875 fps. The underlying zone with a velocity of 650 fps extended to a depth of 22 ft where the third zone was encountered with a velocity of 975 fps to a depth of 45 ft, the limit of testing. The velocity profile through the random zone and into the foundation revealed four zones. The first zone, 28 ft thick, exhibited a velocity of 1100 fps. The second zone which extended to the dam-foundation contact had a velocity of 1675 fps. The alluvium directly beneath the dam had a velocity of 1400 fps and a thickness of about 7 ft. A velocity of 1750 fps was detected at 121 ft deep and is probably indicative of the Black Butte Series. Interpretation of data obtained at the downstream toe of the dam revealed three zones. The first zone, corresponding to alluvium, had a velocity of 675 fps and a 15-ft thickness. The underlying zone also corresponded to alluvium and had a velocity of 1300 fps extending to 27 ft in depth where the Black Butte Series was encountered. The Black Butte Series in the toe area was determined to have a 1825 fps velocity to a depth of 95 ft, the extent of testing.

54. The second interpretation approach (based on constructed zones of the dam) is presented in Figure 25. The core is divided into three zones. The first zone was 12 ft thick with a velocity of 875 fps.

The second zone which ranged from 12 to 22 ft in depth had a velocity of 650 fps. The third zone extended from a depth of 22 ft to the damfoundation contact and exhibited a velocity of 975 fps. The random zone of the dam was divided into two velocity layers. The upper 28 ft of random material had a velocity of 1100 fps. The rest of the random material was interpreted to have a velocity of 1675 fps. The foundation materials were divided into three velocity zones. The first zone corresponding to the near-surface materials at the toe, had a thickness of about 15 ft and a velocity of 675 fps. Underlying the above zone and extending laterally to the transition zone was a layer with a velocity of 1350 fps and an average thickness of about 10 ft. The above two zones corresponded to the alluvial materials. Beneath the alluvium, a velocity

of 1800 fps was encountered which correlated with the Black Butte Series.

PART IV: CONCLUSIONS

- 55. The following conclusions were drawn as a result of the in situ investigation conducted at Black Butte Dam.
- 56. The interpretation of P-wave data indicated three velocity zones in the core and two velocity zones for the random fill. The core had velocities of 2150, 5050, and 3050 fps while the random zone had velocities of 1825 and 3225 fps. The foundation materials investigated consisted of alluvium and materials belonging to the Black Butte Series and Chico Formation. The alluvium on which the dam rests had a velocity of 4400 fps. At the toe of the dam, the 4400-fps alluvium is overlain by alluvium having a velocity of 1500 fps. Underlying the alluvium is the Black Butte Series which had a velocity of 6775 fps. The Chico Formation had a velocity of 9850 fps and was encountered only by the refraction seismic test conducted at the toe.
- 57. Results from seismic refraction tests indicated three velocity zones for the right abutment of the dam. The first zone, slope wash, had a velocity of 1225 fps. The second zone, corresponding to the Tehama Formation, had a velocity of 3500 fps while the third zone, basalt flows, had a velocity of 9825 fps. The left abutment had velocities of 2375 and 8225 fps which correlated with slope wash and basalt, respectively.
- 58. The S-wave velocity profile for Black Butte Dam showed that the core had three velocity zones of 875, 650, and 975 fps. The random zone was interpreted to have velocities of 1100 and 1675 fps. For the foundation, alluvial material in the vicinity of the downstream toe, had a 675 fps velocity and a thickness of 15 ft. For the remainder of the alluvium at the toe and extending beneath the dam to the transition zone, a velocity of 1350 fps was noted. The Black Butte Series, which underlies the alluvium, was determined to have a velocity of 1800 fps.
- 59. Results from surface vibratory tests conducted on the right abutment indicated that R-wave velocities ranged from 640 fps near the surface to 1125 fps at a depth of 37 ft.

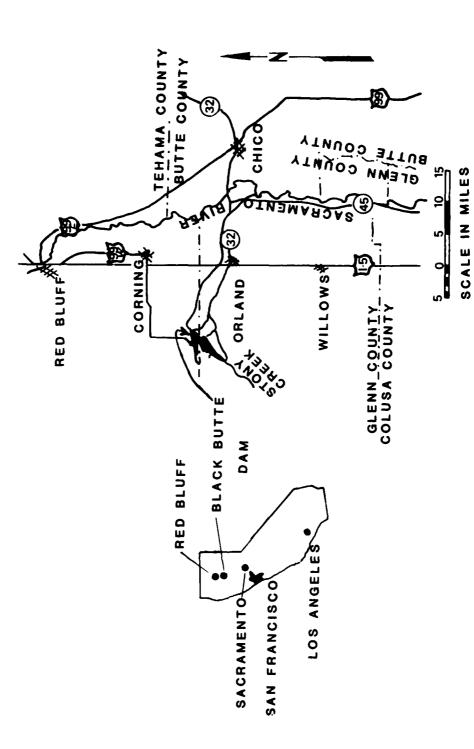


Figure 1. Locality map

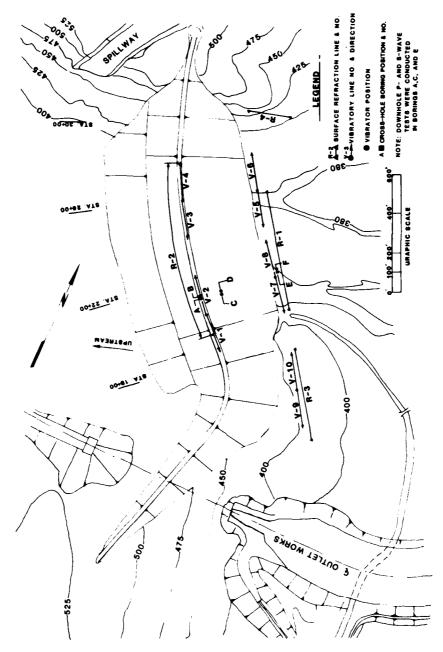
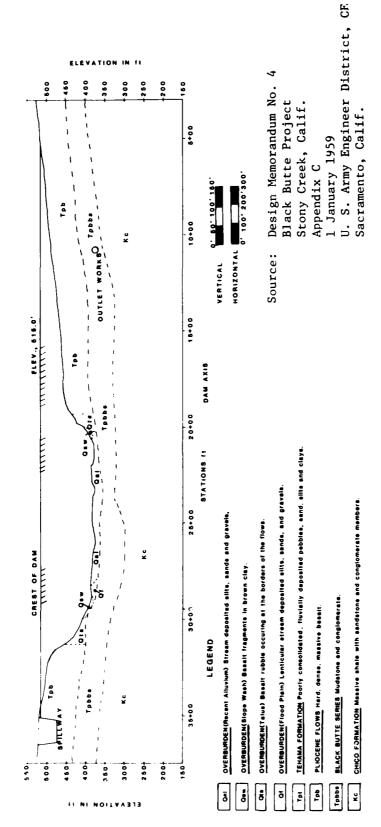


Figure 2. Plan view and test layout of Black Butte Dam



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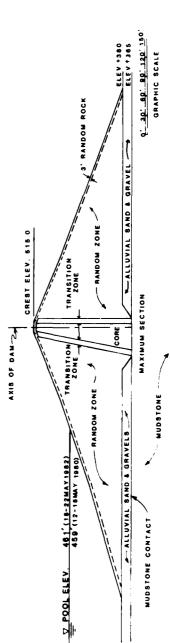


Figure 3. Cross section of Black Butte Dam

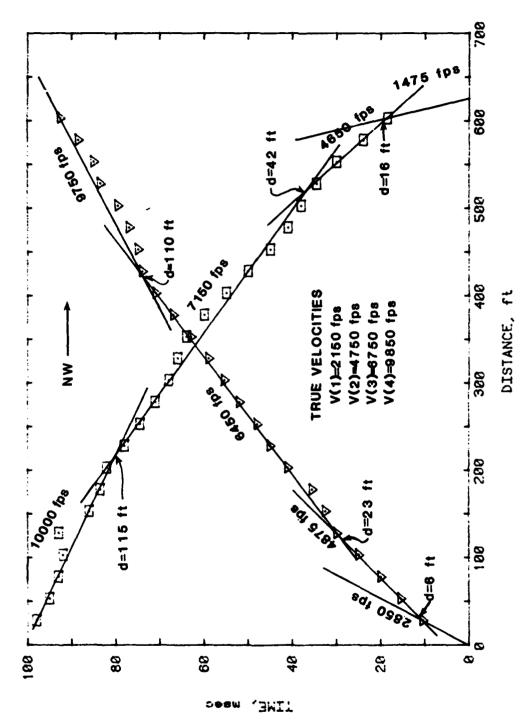
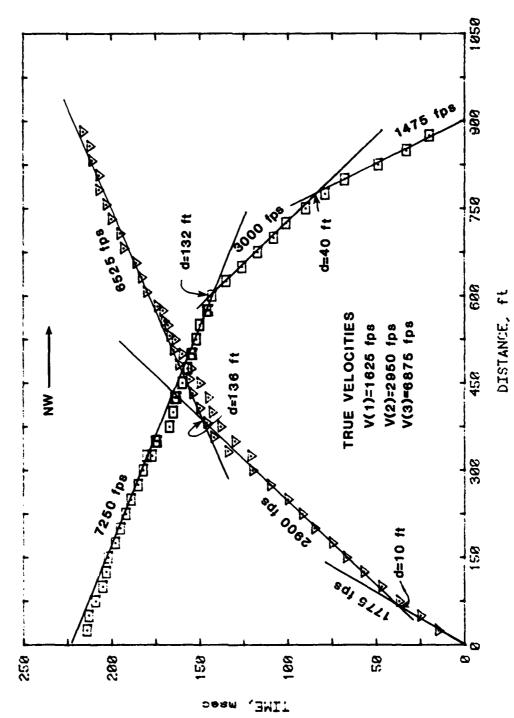


Figure 4. Surface refraction line R-1, toe of dam



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Figure 5. Surface refraction line R-2, crest of dam

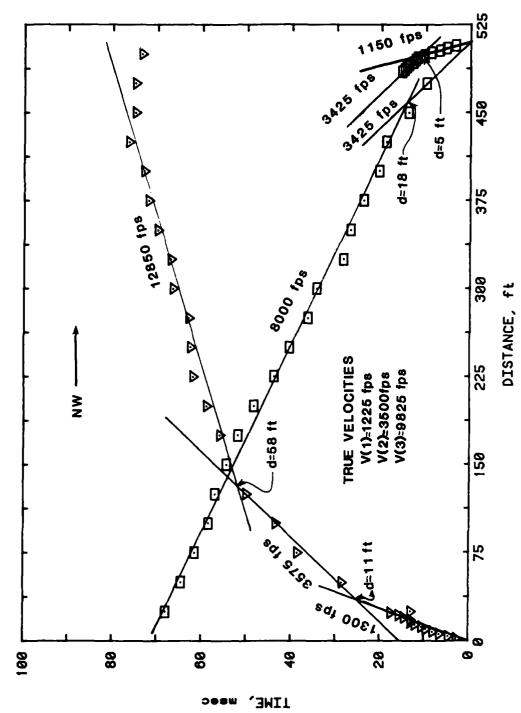


Figure 6. Surface refraction line R-3, right abutment of dam

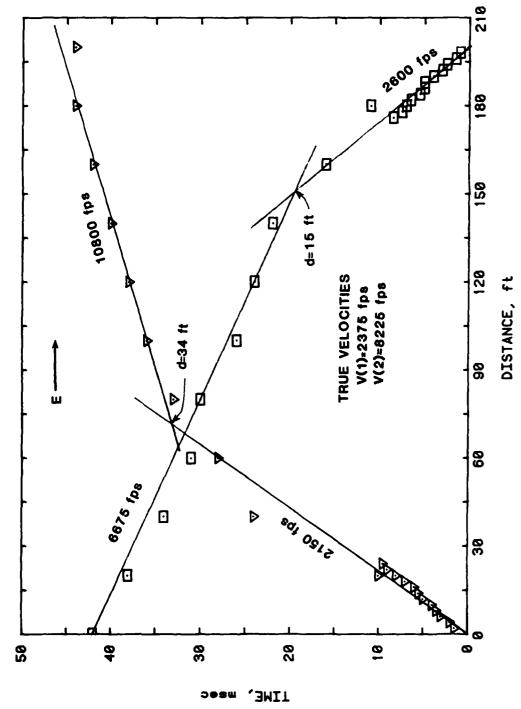
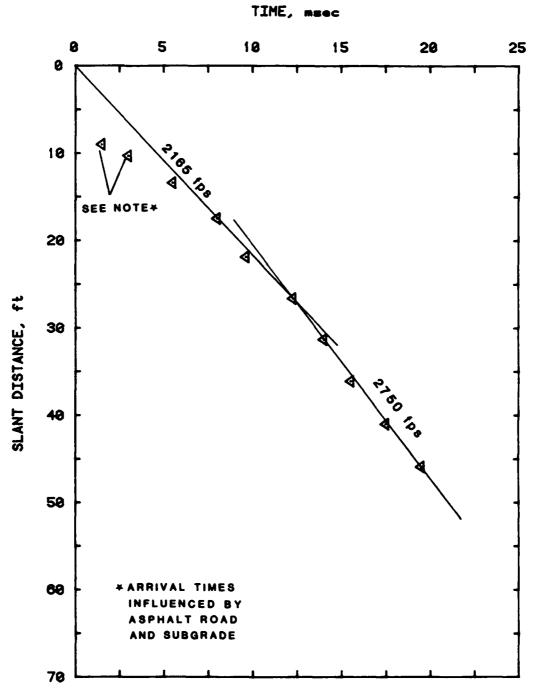


Figure 7. Surface refraction line R-4, left abutment of dam



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Figure 8. Downhole P-wave test conducted in borehole A, crest of dam

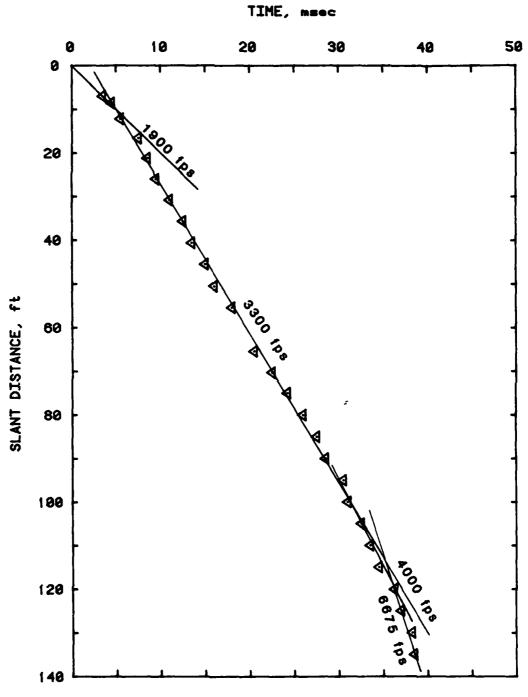


Figure 9. Downhole P-wave test conducted in borehole C, downstream slope of dam

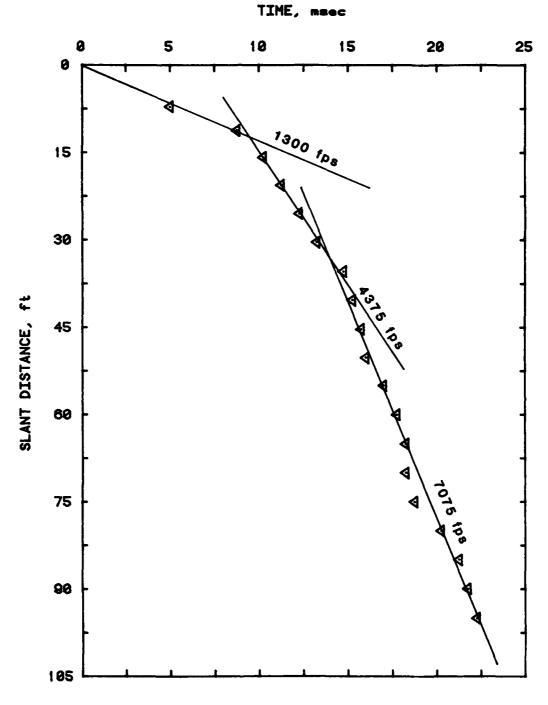


Figure 10. Downhole P-wave test conducted in borehole E, downstream toe of dam

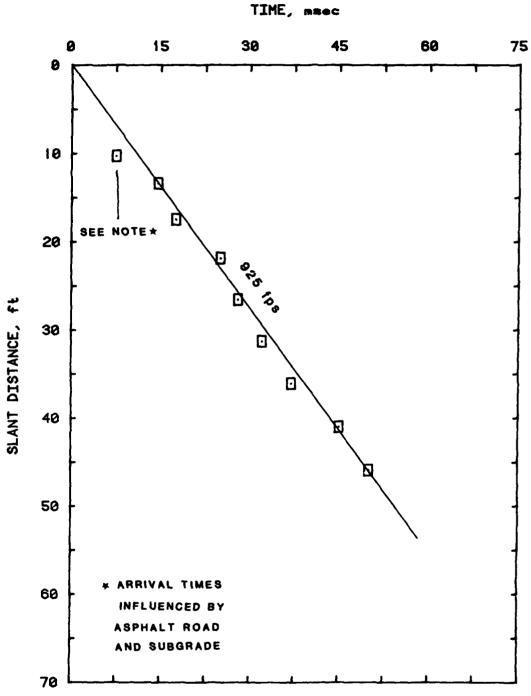


Figure 11. Downhole S-wave test conducted in borehole A, crest of \mathtt{dam}

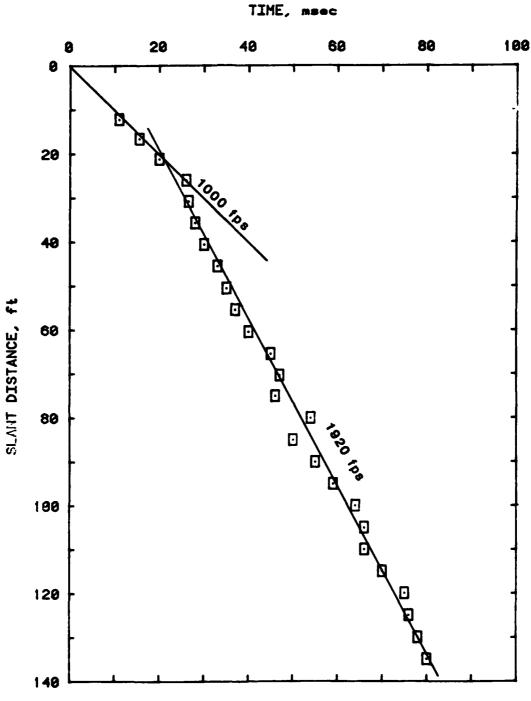


Figure 12. Downhole S-wave test conducted in borehole C, downstream face of dam

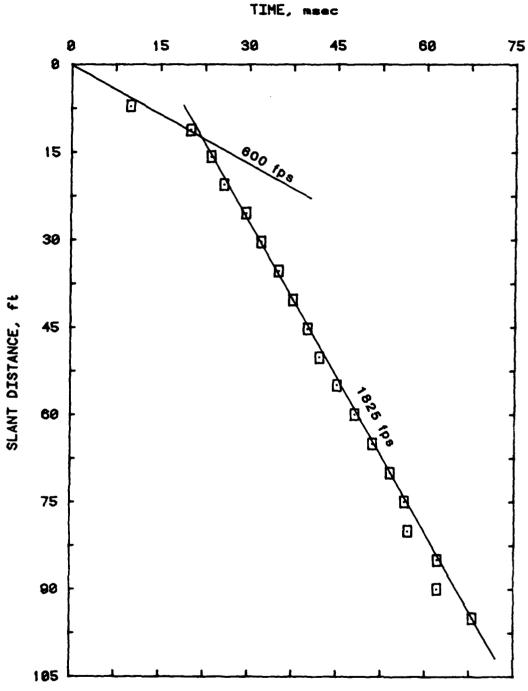


Figure 13. Downhole S-wave test conducted in borehole E, downstream toe of dam

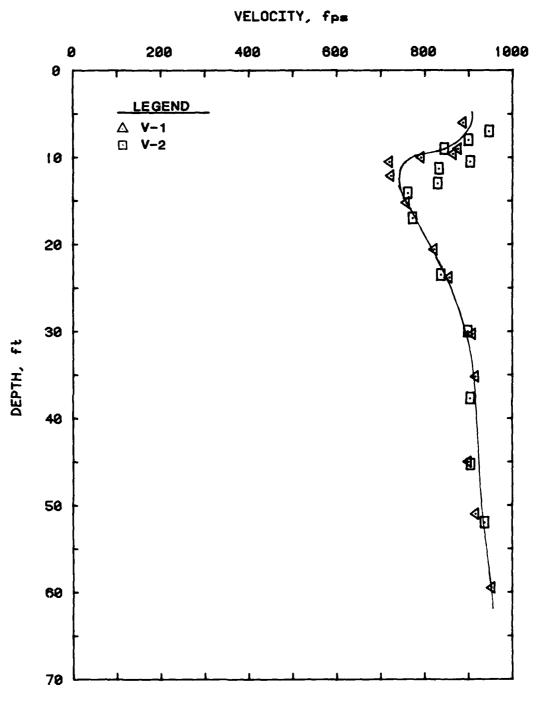


Figure 14. R-wave velocity versus depth for lines V-1 and V-2, crest of dam

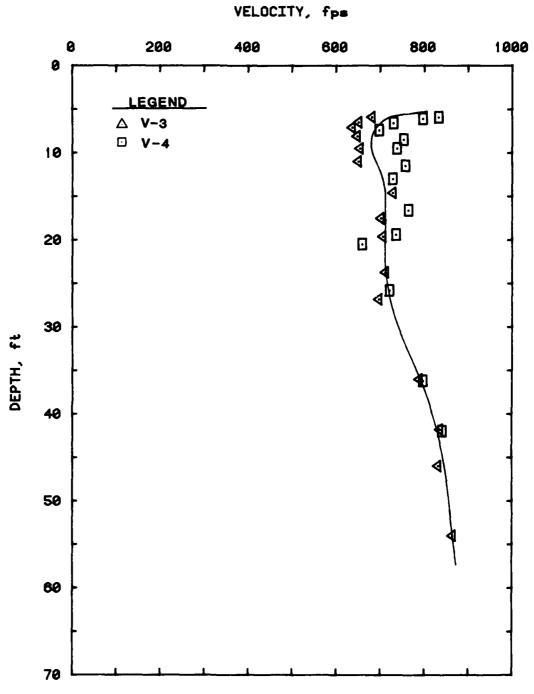


Figure 15. R-wave velocity versus depth for lines V-3 and V-4, crest of dam

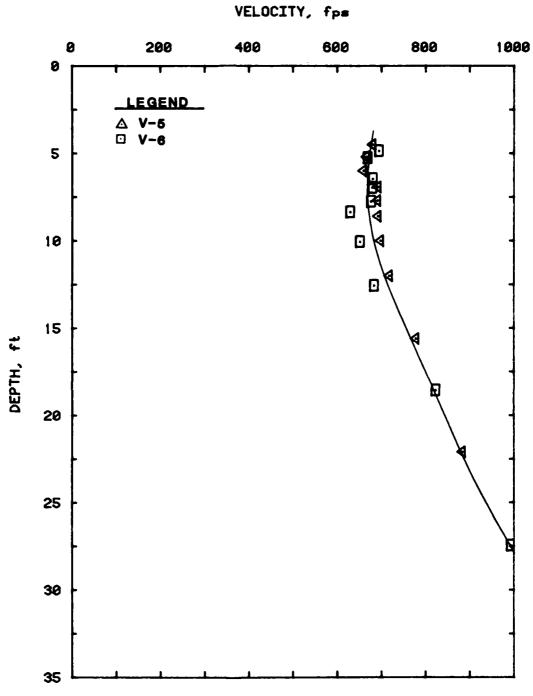


Figure 16. R-wave velocity versus depth for lines V-5 and V-6, downstream toe of dam $\,$

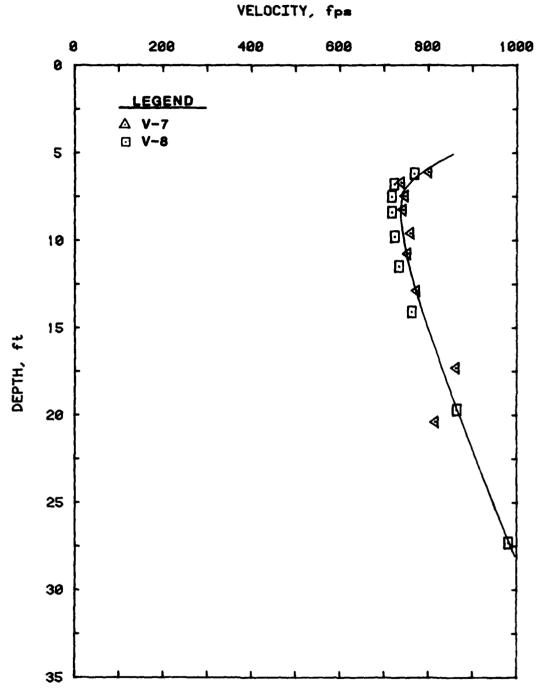


Figure 17. R-wave velocity versus depth for lines V-7 and 1-8, downstream toe of dam

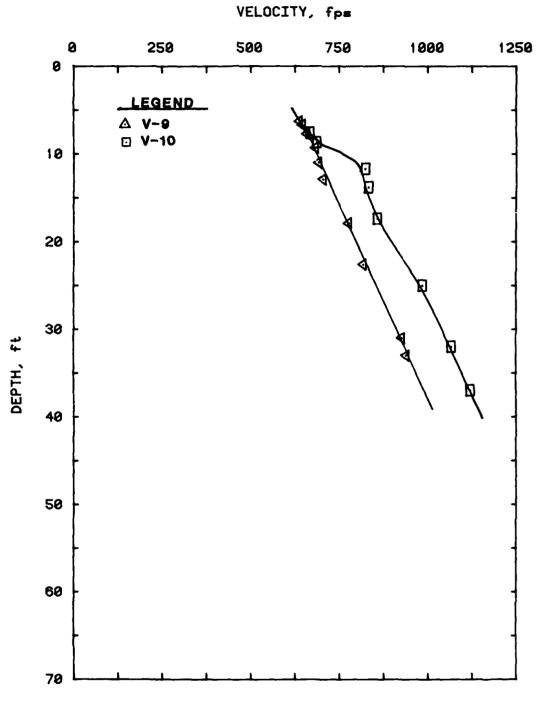
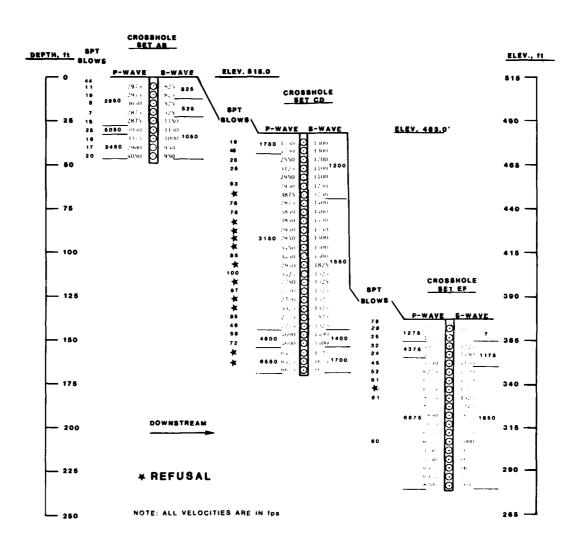


Figure 18. R-wave velocity versus depth for lines V-9 and V-10, right abutment of dam $\,$



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Figure 19. Crosshole results for cross sections through approximate sta 21+00

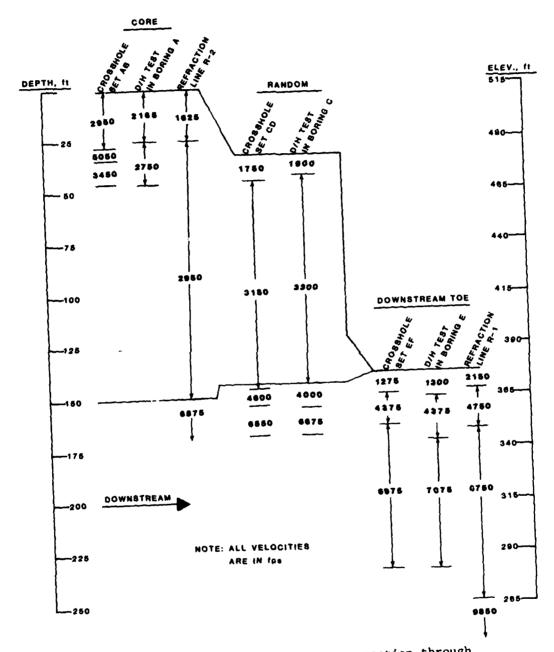


Figure 20. P-wave composite for cross section through approximate sta 21+00

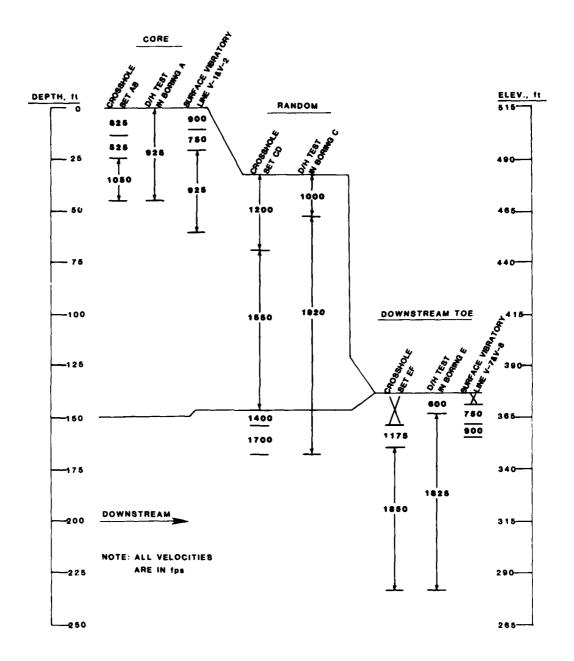


Figure 21. S-wave composite for cross section through approximate sta 21+00

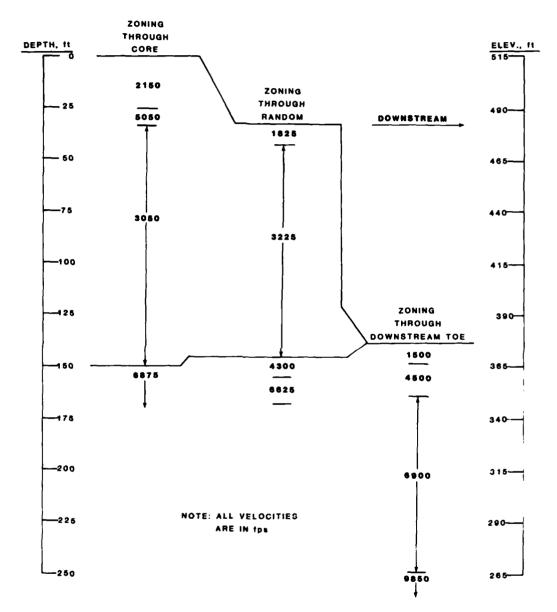


Figure 22. P-wave zonal velocity interpretation for cross section through approximate sta 21+00

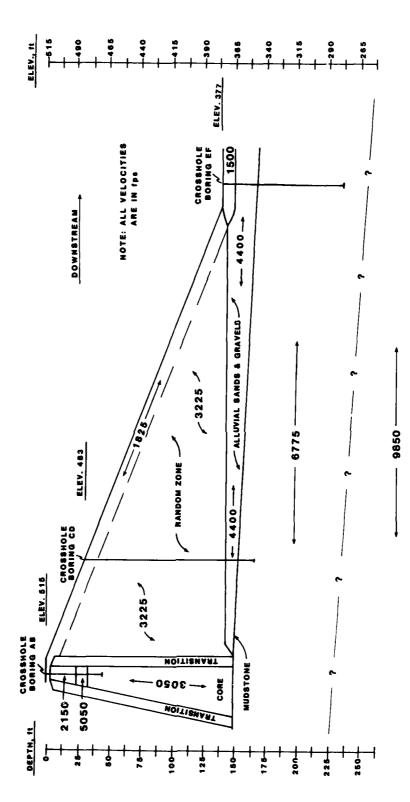


Figure 23. P-wave velocity contours for cross section at approximate sta 21+00

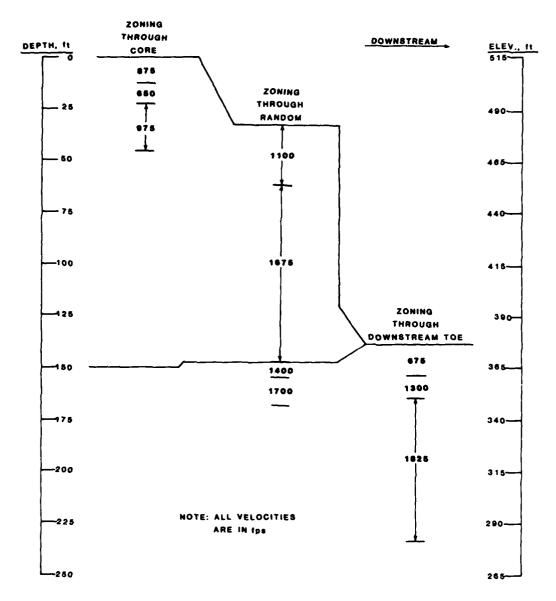


Figure 24. S-wave zonal velocity interpretation through cross section at approximate sta 21+00

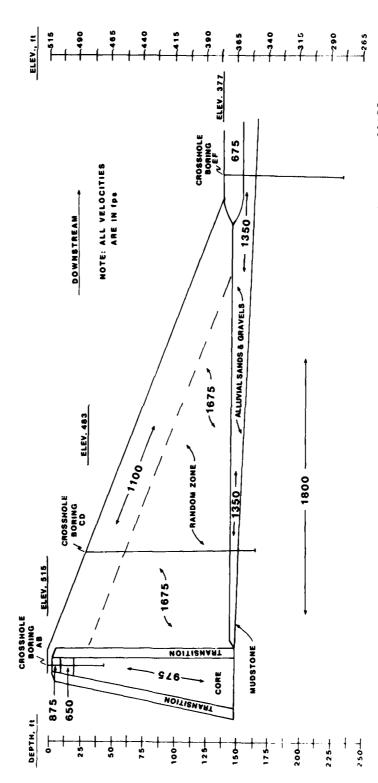


Figure 25. S-wave velocity contours for cross section at approximate sta 21+00

APPENDIX A: BORING LOG FIELD DATA

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5 8ac7	5			24.0		24.4	26.4	5"X6 4 3.200	196	, Killer	26.4 24.4 26.4 5'K6'4 ESER STORE TO 10-BLUE SOUDY CL, HED, GROWEL
90	SOCT			29.0	29.0 31.4		23.6	280 296 5x64 BARREZ	JAL	STUB	DAL STUB TALL BLUE SALDY CL, HED GENORE
2	90cT			34.0		34.2	36.4	36.4 34.2 36.4 5"x643702102 SAD	नुध	Strue.	STUBE THU BLUE SAUDY CL, METS GRANDER
6	90CT			39.0	39.0 41.4	39.4	41.4	39, 9 41, 4 5/6/4 Drever 19-0 5/20	945	Skie	BLUE SAWRY CL MED

	Date 900781	Job No.	Boring No. 2/5-2 1/8	SACRATIC CINE INCIDENTIAL INCI	CLASSIFICATION AND REMARKS	TAN BLUE SAUDY CL THED GRADE		45. 051,4 50.0 51,4 5"x1,6 BREBER JAQ 5"TONE BLUE SANDY CL STIFF GENERA		" I PART GENEUT TO I PART GET WINGER, GROUTING WAS DONE AFTER 4"I.D	CASING UP SET WEAD OU BOTTOM OF PIC. CHECKED WITH 3% STEEL IUST.						
			face El-	Alla	(20	C748-		2,203,5		See	4						
			27 Surf	Wy (R	(78	306		द्व		224	Che						
BORING LOG FIELD DATA	Site		Operator Export Street Per Surface El	l	SAMPLER	44.0 46.4 44,4 46,4 5 x64 BREDE SAL		"XL' KBREPE		ר פבו ט/טו	10F PVC.						
B0			erator 🚣	E	10	× 27%	-	21.4		1000	Sorra						
P			Op.	SAMPLE	FROM	44.9		50.0		27.70	200						
	May		9497	/E	Т0	4.34		3118		GZEE	6/2	•					
	BUTTE DAM	i	מפח	DRIVE	FROM	0%		45.0		9er	ser	20′.					
	Si,		Inspector OC EN LOYD	TUM	10					G/ HT	C CM	1 to 501.					
	BLACK	1.4		STRAT	FROM					Grouner WI	Z/82/X	0 03					
	Ι' Ι	9	CE	DATE	TAKEN	9 OCT		POCT		Grout	PVC	GROWED					
	Project.	Location	Oriil Ri	SAMPLE	NUMBER	6		9		+							

	Date 26 1001 8/	Serface El Boring No. 4554 "C"	CI ASSIBILITATION AND BEINABKS		Clean Our Hale	C/earl Out Have	Q	Crean out Hale-Lost Dit	AND GUIDE NO HAK- ROD SNAPPED	FISMED OUT BIT AND DISCOVERED	large You Due to FALL NO OF	1605G GrAVEL FROM THE WALL.	YOLD DEGIUS I UST ANDER THE	4 Ft THICK CONCRETE DASC	USED AS GUIDE hole	Grout Hole WHARD GROUT	2 bbls grout USED TO Fill VOID	AND HOR UP TO CONCRUTE BASE	
BORING LOG FIELD DATA	Site	Operator STEWPRT	TYPE OF	SAMPLER	6 1 Rax Bit	8 Pack But		6% Rock But											
ωI	700	Operator S	SAMPLE	FROM TO		+						_							
		ار ا	/E	T0 F	0.01	0'0/		13.0											
	TE DAM	76%	DRIVE	FROM	0.0	0.0	Į.	10.0											
	3773	Inspector 704	STRATUM	10															
	27	3		FROM															
	Project BLACK By	Location 16 77 Spure	DATE	TAKEN	16.NO	26 200		26.460								23 NOV			
	Project	Locatio Drill Ri	SAMPLE	NUMBER															

Sheet / of 1

	ļ ļ						<u>سا</u> س	BORING LOG FIELD DATA		
Project 34766	126	36	1776	DAM	-			Site		Date 28 JOV 8/
Location 10 ft	4	5047	30	55.3	ľΙ	TSWAST	REA.	DOWNSTREAM SLOPE		Job No.
Drill Rig SKID	417	Inspector ZOH	tor Z	HO		ope -	erator ≤	Operator STEWART	Surface El	e El Boring No. <u>4558</u> "C"
<u></u>	1	STRATUM	-	DRIVE		SAMPLE	m.	TYPE OF		SAGANDE AND DE MADIC
NUMBER TAK	TAKEN	FROM TO	\vdash	FROM	T0	FROM	10	SAMPLER		CLASSIFICATION AND REMARKS
28'	28 NOV		7	4.0 3	35.0			634 ROCK BIT		CLEAD OUT HOPE OF GrowT
									_	THED Drill to 35,05+
28 AOV	707									Grout Hole W/SOCT GrowT
				_						1/2 bbls Grout Used
YOR	30 Abov		53	35.0 S	57.0			64 ROCK BIT		CLEPI OUT HONE
		-	\dashv					116		
1060	29	-	12	52.0 87.0	7.0	+		CE ZOCK BIT		CLERN OUT HOLE
77	DEC		63	87.0 126.0	0.0			C.3" ROCK BIT		CLEAD OUT HOLE
									_	FOUNDATION BEDERGK @ 116.0
									_	Oppears to he SILTSTOLE-Play with
 										drae Rocks WIERHINES by drill
										effect to 120.0
	-	-	_	-						
3000	১		72	120.0 12	121.0			67 RachBir	-	CLEAD OUT HONE

							<u>.</u>	BORING LOG FIELD DATA		
Project	Project BLPCK	1	777	BUTTE DAM	I			Site		Date 3 Dec 8/
Location	Location 10 ft Soury	Soun	70%	06 553		Power	STRE	DOWUSTREAM SLOPE		Job No.
Drill Ri	Orill Rig SKID		nspecto	Inspector 70H		6	perator S	Operator STENART	_ Surface El	El Boring No. 45399 "C"
SAMPLE	DATE	STRAT	TUM	ě	DRIVE	SAM	SAMPLE	TYPE OF		
NUMBER	TAKEN	FROM	10	FROM	Τ0	FROM	то	SAMPLER		CLASSIFICATION AND REMARKS
,	3206			121.0	121.0 123.0,23.0 123.0	123.0	123.0	5x6/4		NO SAMPLE RECOVERED. SEDERAL
									_	TERM OF BIT WERE DESTROYED
										AND/OF Broken OFF
	3 DEC			123.0	0.52/0.52/			6 74 Rect 817		CLERN OUT HOLE
7	3000			125.0	126.0	125.0	125.9	125.0 126.0 125.0 125.9 5x6/4	7.08	TUBE CLANKY SLIBTONE - DARK TO LIGHT
2 A						125.5	126.0	125.5 126.0 Cope BOPEE	JRZ.	19R GREEN COLOR - VERY COHESINE
									-	LITTLE HOISTURG-SOME WART BRITLE
	1907			1240	126.0 /30.0			1. Fran Bit		C. EBL) Our Hole
3	4 DEC			130.0	131.7	/30.3	13/.6	130,0 131.7 130,3 131.6 5 16/4	7484	TUBE CLAYEY SICTSTOLK-UPER, GREEN
34						/3/.6	13/7	131.6 151.7 Case BARRET	SAC	SAR YERY CONESIVE-LITTE HUSTORE
									1	Somewhat Brittle
	7207			13/3	13.5			6 % Rocker	-	CLEAN Dut Hole
								1.7 27.7		

	Surface El Boring No. US3A	C. ASSIFICATION AND REMARKS		TUBE CLANEY SILTSTOING - DARK GREET	JAR JERY CONSTINCTURE HUSTURE	Beitte	THAT CLAYED SUTSTOWE - DARK Greed	LAR 2) ERY COMESIVE - LITTLE HOSTIVE	Brithe		4-in PVC Casius, Growted wPlace	UX Bornel HARD Grout From	40.5' to 116.0'	SOFT Grout 31/2 BBL From	116.0' to 0.0 4.		
BORING LOG FIELD DATA	DOWNSTREPH SCOPE OperatorSTEWART	TYPE OF	SAMPLER	135,5 1380 135,7 133,7 5x6/4	137,7 138.0 Core BARRE/		138.0 140,0 133.0 140,4 5x6 14	140.4 HOS CORE Borrel									
W	TREP!	SAMPLE	10	137.7	138.0		1,0,4	105									
ļ		SAN	FROM	135.7	132.7		/33.0	140.4	_								
	A	DRIVE	10	1380			140.0										
	OF SS3 Pector TOM	D. P.	FROM	135.5			138.0										
	Butte D	TUM	٥														
	L KE	STRATU	FROM			-				,							
	Project BLACK By Location 1054 South Drill Rig SKID Ins	DATE	TAKEN	2506			4Dec				4062			SDEC			
	Project. Location Drill Rig	SAMPLE	NUMBER	4	44		5	5.4									

Project BLACK. Location Double Drill Rig SAMPLE DATE TAKEN FR ROCK B 21/NOV 5.2

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						}	6 01 4-	BORING LOG FIELD DATA			
Project	Project BLACK	CK BU	UTTE	DAM	7			Site			Date 21 OCT & I
Location Drill Rig	Location Downsing	7	TREAM SLOPE	EAM SLOPE	7607		Arotera	Onerator Fe BOK STEW & E.T.	1	face F	Job No. SS-3 "D"
	- F		on ander				- Dan Io		8	8	
SAMPLE	DATE	STR	STRATUM	DR	DRIVE	SAM	SAMPLE	TYPE OF	11/6/	کئ	SAGAMAG CINA MATERIALISM 19
NUMBER	•	FROM	7.0	FROM	7.0	FROM	Т0	SAMPLER	(00)	2 Co	CLASSIFICATION AND REMARKS
	ROCK BIT		C,42	70 28	8.0'4	2576	Purcell	3/1") To 28,0' LARGE PHOUNT OF PER GRAVEL	FRAVE		COMICS TROM HOLE.
	1267	Des	35/1	neo.	J. Was	VC FR	A MO	Churry TA	parox.	4/5	THEY ARE TO THE WED COMING FROM A CAUTY TRAINS, IN DOWN, GrounED HOLE WITH
	Jan.	JAMENT-6	1 100	IXTUN	16 11	200	1078	IN CHLOS	· Joh	3	ET MYTHE USING PALCIUM CHLORIDE TO THE FETH TO SET 22 BETSI
	rsch	1% B	S C	CW6	ر را را	28	6,00	el Hivedu	on Hylo	TER	1% BACS CRUPAT & 1/2, Bace Gel 41 wed with waters, This File & 46/4 to
		200	30CT	77 18	ed ;	do S	9 - S	MEAT & 2	ZACS	-235	AN 23 OCT BILLISC A TEACS COMENT & 2 TENGS GET ! CALCIUM CALORIDE MIXED
		Con	7.2	115 Z	1/64	4610	\$ 60	177.			
								1			
15	240CT	24.5		28.0	, ss	28.5	29.5	28.0 28.5 28.5 29.5 SRITSPOOL	JAR	53	JAR 53 CONESE GUNY SAND - STIFF
				26.5	28.5 29.0					33	PBOUT O.Z TANCL PT BOTTOH
				0'52	29,0 29,5					38	30 OF SAMPLE
									-		
S,	26.0CT			33.0	35.5	38.3	35,9	35.0 35.5 35.3 35.9 SPLITSPOONJAR 20	MJAR	97	CORRSE GRRY SAUD-STIFF
				35.5	35.5 35.9				_	20	
	GROW	GROUTED TO)	1/10	שני מי	2'6/7	16	neut/Who	200	CIU	9.DEPTH DE NO WITH COMEUT/WATER COLUMN CHLORIDE. Growt
	233	1500 5-55		022	300	22 70	27/3	4016 .92	200	me	GAL ORISO GALTO FILL HAVE S BUS COMENT USED. THIS WAS
	Dove	Bee	35m	K 20	10/64	000	Cen	DOUG BECAUSE OF FOLLUPG OF COMPLUT-GO HIXTURE	HIXTE	e e	

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	Date 27 OCT 81	Job No.			CLASSIFICATION AND REMARKS			COARSE GRAY SAUD W/FEW 3/4"	GRAVE - STIFF		25 COAKSE GREAY SAUD WEEN GRANET	STEF- SHALL PHOUNT OF	7AU CL.		COARSE TAD/GRAY SAND-STIFF	•		COASSE THEY GRAY SAUD-STIFF	SO SOME GRAVET.	
			fface E	73	و2 د	duT.	1	6/	33	43		33	45		50	So		25,	S	
			2 5 S	P. C.	روح	96	eau	JAR			J _R	_			4		_	8	_	
BORING LOG FIELD DATA	Site		pector OLEW LOYD Operator FRANK STEWART Systace El	TYPE OF	SAMPLER	BIT BACK TO 20' THEWISH CONCRETE GROUT	TO 40 THROUGH CONCRETE GROWT	40,5 40,5 41,5 SPR.175POON JAR 19			45.0 45.5 45.3 46.5 SPLITSPOOD JAR				SPLITS POOUS JAR			55,5 55,1 56,0 SPL/TSP00N JAR		
101			erator 💪	LE	10	HS FO	HC	41.5			 46.5				J			56.0		
			do 2	SAMPLE	FROM	2, 2	Rout	\$6,5			 45.3				2/1/2			\$5.7		
		150	100	E	2	20	0,7	10.5	07/	1.5	 15,5	200	16.5		27.5	8773		55.5	200	_
	1 1	' '	737	DRIVE	FROM	BACK	79	0,0	01/6 510	51/10 01/10	 15.0 5	45,5 46,0	16.0 16.5	+	51.0 51.5 51.1 51.8	51.5 51.8		55.0	55.5 56.0	_
	Butte	14815	spector	NA CIM	ę	26,7	317	3	-3	3		7	-		7	8		7	7	7
		USTR	lns	STRATUM	FROM	20ck	POCK					-		+		+	+		-	-
	Project BeACK	Location Downsme		DATE	TAKEN	27 Q.T	ZSQT	28 CCT			 280CT				280c7			280CT		-
	Project	Location	Drill Rig_		NUMBER	7	Ň	7 + 7			#8 2				6 *			10 2		

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Project BLACK BLATTS Location Douglo Stocker Slock Constitution Deliver Shall Stevensor Erratum Drill Rig Inspector Oleso Loy D Operator Erratum Drill Rig Inspector Oleso Loy Doerator Erratum Drill Rig Inspector Oleso Loy Doerator Erratum Drill Rig Inspector Oleso Loy Brown To From To								20 1 m	BORING LOG FIELD DATA			
DATE STRATUM DRIVE SAMPLE TYPE OF SAMPLER TAKEN TO FROM TO FROM TO FROM TO SAMPLER TYPE OF SAMPLER TAKEN TAKEN TO FROM TO FROM TO SAMPLER TAKEN TAKEN TO FROM TO FROM TO FROM TO SAMPLER TAKEN TAKEN TAKEN TO FROM TO FROM TO SAMPLER TAKEN TA	Project_	बाह्य	7	TT WE]	JA C			Site			Job No.
DATE STRATUM DRIVE SAMPLE TYPE OF SAMPLER TAKEN TO FROM TO FROM TO FROM TO FROM TO FROM TO SAMPLER S	Location Drill Rig			Inspecto	JO.	7012	1 1	erator E	RAUK STEWAR	١, ١	face El	Boring No. 55-3 "D"
300C 85.0 85.2 86.0 SRLITSPOOD DR 300C 85.5 86.0 SRLITSPOOD DR 300C 85.5 86.0 SRLITSPOOD DR 300C 85.5 86.0 SRLITSPOOD DR 300C 90.5 90.5 90.3 90.4 SPLITSPOOD DR 300C 90.5 90.0 90.5 90.1 90.5 90.0 90.5 90.1 90.5 90.0 DR 300C 90.0 90.5 90.1 90.5 90.0 DR 30.0 DR 30.0 PR 30.	_	DATE		TUM	a l	IVE	SAM	PLE		C S	2	CLASSIFICATION AND REMARKS
300c7 850 855 860 SRITSMOD JAR 3 310c7 90,6 90,5 90,3 91,4 SPLITSMOD JAR 3 91,0 91,5 95,1 86,9 SPLITSMOD JAR 3 4 NOV 40.0 (20,0 G 34" Reck BIT 100,0 SPLITSMOD) JAR 3 6 NOV 100,0 100,9 SPLITSMOD JAR 3		TAKEN		0,	FROM		FROM	٤	1	EVA.	à de	
31007 90,6 90,5 90,3 91,4 SPLITSMOUD JIPR 3 31007 91,0 91,4 91,0 91,4 91,0 91,4 92,0 95,1 95,9 SPLITSMOUD JIPR 3 4 NOV 40.0 600,0 63,4 REK BT 600 SPLITSMOOD JIPR 6000 100.9 100.0 SPLITSMOOD JIPR 60000 100.9 100.0 SPLITSMOOD JIPR 600000 100.9 100.0 SPLITSMOOD JIPR 60000 100.9 SPLITSMOO	1	300CT			850	85,5	88.2	098	}		_	GRAY COARSE SAUD-MED.
3/027 90,6 90,5 90,3 91,4 SPLMSPOOL) JAPR 3 91,0 91,4 91,0 91,4 91,0 91,4 91,0 91,4 92,0 95,5 95,1 96,9 SPLMSPOOL) JAPR 3 5210V 100,0 100,9 100,1 100,9 SPLMSPOOL) JAPR 60,000 (634"Rexent					85.5	86.0					20	
4 NOV 100,0 105,0		1			9	6	208	7 10		IBR		GRAY COARSEARUD - HED
31027 95.0 95.5 95.1 95.9 SPLITSPOOL) JAPE - 95.00 100.0 100.0 100.5 SPLITSPOOL) JAPE - 100.0 100.0 100.5 SPLITSPOOL) JAPE - 100.0 100.9 105.0 1	T	78			5,5	9%	2				7 " 1	
31027 95:0 95:7 95:1 96.9 SPLITSPOOL) JAR. 4 NOW 40.0 100.0 100.9 SPLITSPOOL) JAR. 5.NOV 100.0 100.9 100.L 100.9 SPLITSPOOL) JAR. 6NOV 100.9 105:0 634"Rexert					076	7116					51	
5.00 (20.0) (21.	1				6/10	0,00		0%	CONTRADOL	190		CADU PORDSE SAND-STIFF
5.00V (00.0 (00.0 (634"Rek BT 5.00V (00.0 (00.9 (00.2 (00.9 SPLITSPOOL) JAR 6.NOV (034"Rek BT	1 1	70/2			55.5	6,29		\$				
5200V 100.0 100.8 100.2 100.8 SPLITSPOOL) JAR 620V 100.9 105.0 634"Recket	1	4 1/0/			40.0	100.0			63/4"Rock B.T			CLERY OUT HOLE HIT FOURMATION COMO"
100.9 105.0 634"REXENT	1 1	SUOV			100.0		100.2	100'	SPLITSPOOL	JAR		25 GERY SAUDY HIL- FINE to HED, GERY
100.9 105.0 634" RECKBIT					11					-	5	SMALL RS Red GOAVE LIDITED
		/o/Vo/			9.001	, 105.1	1		634" ROCKBIT	-		CLEAN OUT HOPE
FORM OID	1 2	2	4			30 20						Sheet S of 10 Sheets

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	Date 6. NOV 8/	Job No.			CLASSIFICATION AND REMARKS	27 SAUD-GRAPE, GIVE to 1908 30%	45 GROWEL-GRAY WHITE 3/4" HAX	50 GOOD COUSOLIDATION LITTLE HOSTURE	GROUT HOLE FORM 1045 CH to 4115 CH	1209A The. 135 645 AcTUAL	1:1 cont/6er W/c = 3.2?	REAN Our Hole 41,5 to 106.5 Ft	JAR 40 106,5 to 166.9 CLAY WERNEL	50 34"GEAM, deuse, MAST	106.9 to 167.3 SANDY GARVEL	FINE to Ked SAID GRAP- GAME	1, " HAX GERY WSOME CHINE PCS	Fre CousoldAMO LIMA HOLGURCE		CLERY OUT HOSE	
			Surface El	30	200	52	45	50		_			9	20				_			
}			S	- ANIE	*LOGS	JAR												_	_		
BORING LOG	Site		Operator STENDET	TYPE OF	SAMPLER	105,0 106,5 105,5106,5 SPC, 15000						634 ROCK BIT	106.5 107.3 106.5 107.3 Sep. 12.00)							6 % ROCK BIT	
al L			erator _	SAMPLE	10	106.5							107.3								
			0	SAMI	FROM	105.5							106.5								
		(د'		E C	10	2700						106.5	103.3							0801	T
	Dam	3008	Ton	DRIVE	FROM	105.0						41.5 106.5	26.5							103.3 1080	1
	KTIE	ſ	Ō	LUM	TO																1
	K B	SYRE	<u> </u>	STRATUM	FROM																٦
	BLAC	Lough	SKID	DATE	TAKEN	6000						400%	10076							1007 6	
	Project BLACK	Location Townsyren	Orill Rig SKID	,	NUMBER	20 6						6	421 9							6	7

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					}	gol "	BORING LOG FIELD DATA			
Project BLACK Burre DAH	OCK BE	Take D	SINE		1		Site			Job No.
Orill Rig SZ1D	di.	Inspector TOM	TOH Y		ő	erator S	Operator STEWART	S.	Surface El	
<u></u>		STRATUM	DRIVE	VE	SAMPLE	PLE	ĺ	426	500	SAGALLER CITE ACT TO STATE OF THE SAGE OF
NUMBER TAKEN	N FROM	10	FROM	10	FROM	10	SAMPLER	Yes.	070	CLASSIFICATION AND REMARKS
40W9 25	71		108.0	0%01	108.0	0701	108.0 109.0 108.0 109.0 SPLITSTOOL JAK	Jak	50	50 CL BYEY SAUD GRAVEL-SAUD V
									50	50 EIN & GRAY-GRAVE / 34" HAX
										WWATE PES INTERNIMED
										CLAY SASE, VETY COMOSIVE
										FOIR MoistyRG
_	-									
4001	3	_	105.0	109.0 109.5			634 80x BIT		1	CLEAN DUT HOLE
3 9/101			101.5	0'///	10.01	///.0	104.5 111,0 110,0 111,0 Serrspood	निह	20	PR 20 ALPYET SALD GRAVEL-SALDGRAY
	 								24	2 & FING. Gravel 1 16" HAR DAITE
									22	Rock Werny Gravel acs
										CLAS LASE COAR LITTEL CHESION
										little Mostribus
+	-	 					2		1	
10 40/	8	-	0'//	111.0/114.0			63/1 Pax BIT		1	CLEAN OUT HAR
-	-									
$\frac{1}{2}$	1									

	 	}	}				<u>₩</u> "	BORING LOG FIELD DATA			
Project	Bea	Project Benck Bu	Line	1 7 7	T .			Site			Date 10 200 81
Locatio Drill Ri	Location Character Print Rig SK/D	5	Inspector 704	1 2	STOPS	0	erator S	Operator STEWINET	Sur	Surface El	1 Boring No. 55-3 "D"
SAMPLE	DATE	STRATU	TUM	, g	DRIVE	SAMPLE	J.E	1	N. A.O.	P.C.	
NUMBER	TAKEN	FROM	٥	FROM	Т0	FROM	TO	SAMPLER	in Co	ð,	CLASSITICATION AND REMARKS
#7#	Lowa			1/4.0	5'5//	11411	18.5	114.0 115,5 114,1 115,5 SPLITSPOOL) JAR	JAR	11	SAUP- HED to CORSE GRAY
										33	Graved 14" MIK GRAPK WHITE
										25	25 LITTLE MOSTURE No COHESION
	10000			115.5	115.5 118.0			6% Rex BIT			CLERN OUT HOPE
											116.0 to 1/7.0 Secto Book
											CLA:- HUDSTONE @112.0Ft
#25Z	10000			118.0	119.5	118.1	1185	118,0 119,5 1118,1 (119,5 SPE, 175 POW)	å)/	16 CLAY-HUDSTOLKE-GRAVISH GRAVEN
									1:34	27	13th 27 To Gevery Hick collession little
										45	MOSTURE
	/ON 9/			119.5	119.5 121.0			634 ROCK BIT			PLETAL DET HOLE
			_								
*26	Jod of			121.0	122. 4	1210	122.4	121.0 122. 4 121.0 122.4 SQUISPOOL	7	17	17 02 C+ K. FINE SAND @121.8
									1,254	200	1.254 28 CLAY MUDS TOWN GREET HICH
										50	50 COMESION 1.4Ke Moistures

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	Date // 1000 8/	Job No. 25-3 "D"		C. ASSIFICATION AND DEMADKS		CLEAN CUTHOLE	25 CLAY-HUDSTONE, GREET	SO Downse Sould 1ft Proce	CLEAN OLT HOPE		JAK 45 CLAP MUDSTONE CARGED BOWN	53 Gueruch	CLEAN OUT HOLE		2 CLAY HUDSTAVE GREEN	so Deruse Solid IF+ Prece	
1		Surface El									DE C	2			Ag 32	3	
BORING LOG FIELD DATA	Site	Onerator STRESPET		TYPE OF	SAMPLER	(34' BIT	125.0 /26,0 /75.0 /26,0 SPC,75 mod) JAR		12,167		121.0 130.0 127.0 130.0 \$2175000		6 34 8.7		133,0 134.0 133,0 134,0 Splitspood JAQ	\	
91 -		erator .	T Samuel	LE	10		126.0				130.0				1340		_
		٥	} 	SAMPLE	FROM		6.5.Z			9	012)				133,0		
	MAG	SLOPE OH		Ψ.	Т0	0.32/	126.0		24.0		130.0		133.0		134.0		
	29	107		DRIVE	FROM	0'57/ 6'27/	125.0		126.0 129.0		1200		130.0 133.0	-	1330		
	Burre	Inspector TOW	Diabete I	TUM	TO												
	TSLACK B	3		STRATUM	FROM						1			-			
	134	Location Thomas Report Inc.		DATE	TAKEN	11 NOV	1000		"Hoy		" NOV		//00/		Noal		
	Project	Location		SAMPLE	NUMBER		27				907				#29		

Sheet 9 of 10

_ Sheets

	Date 12 NOV 8/	Job No.		STORTING CITE OF LOCATION TO	CLASSIFICATION AND REMARKS	CLEAN OUT HOPE	137.0 137.8 137,0/137,8 Species pood TAR SI CLAY-HUBSTONE DALK GrAY	SO SOULD DETEN . 8 H PLECE		Growt Rottom 20 tt w/ STRAIGHT	CEMENT AND ENDINE AMOUNT LIGHT	Front Upper 1204 w/1:1 2800	of Certain AN GEL WENDER	WATER FOR A PURPOSHIR HITHER	APPROX 12 3 OM. Grout WAS	placed Album THE 4 IN ID	PVC Pipe.	WATER LEVEL @ 98.8Ft in	PVC Pipe,	-	
			Surface El				2	ટ													
			<i>⊼</i>	L			JAP														
BORING LOG FIELD DATA	Site		Operator STEWBRT	TYPE OF	SAMPLER	6 3/ Rock Bit	Speirspood														
)8(r		}	rator S	31	10		378											~			
			ð	SAMPLE	FROM		133.0														
	HB	20		E	10	137.0	137.8														
	UTTE DAM	2000		DRIVE	FROM	1340 137.0	137.0														
	Bun	REAM	spector	TUK	TO																
	1	125 MM	=	STRATUM	FROM																
	BIRK	70	SKID	DATE	TAKEN	12 NOV	12 NOV		-												
	Project	Location DOWN STREPH	Orill Rig SKLD		NUMBER		30 //														

Sheet 10 of 16

	Date 18 Sept 81	Boring No. 55-/ "E"		CLASSIFICATION AND REMARKS	GRAY SAUD & GEAUGE			GRAY SAUD & GRAVEL			GEAY SAUD, FING				Gray SAND COOKSE			
		ırface !	50	, A	60	3	4	3	32	38	*	2	<u>_</u>		21	<u> </u>	=	
		27. St	No.	(ne.)	Sp.			245			JAR			_	JAR	_		<u> </u>
BORING LOG FIELD DATA	Site	Operator Fenux Stewart Surface El	TYPE OF	SAMPLER	SELTSPOOL			SPLITSPOND			SPLITSPOON				Choodery 8			:
901		erator Z	'LE	то	۱,5			3.0			4.5		-		6.0			
		o	SAMPLE	FROM	0.5			1.7			3.5				2,1			!
		040	/E	то	2.0	07	1,5	 2,0	2.5	3.0	3.5	4,0	4.5		5.0	5,5	0.9	
	Het THE	Inspector Ocal COVD	DRIVE	FROM	00	2.0	7.0	1.5	2,0		3.0	3.5			4.5	5.0	5.5	
		nspector	TUM	т0						3,0			4.5					
	77	3 1	STRATUM	FROM	0.0						3.0				4.5			 -
	Project Bear Bu	Drill Rig Ca 4522 In	DATE	TAKEN	18557			Aser			19 Sept				RSETT			
	Project	Location Drill Rig	SAMPLE	NUMBER				2			B				7			

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BORING LOG FIELD DATA	Site Date 1954erTB1	Operator FEARUK STELLU ALT Surface El Boring No. 55-1 'Ell		SAMPLER CLASSIFICATION AND REMARKS	SPRITTERON JAR 6 GRAY SAND COOKSE	7	5	SRITSMON JAR 4 Gray SAND, COOKS	,	01	10.5 SPLITSPOON JAR C GrAY SAND COAYSE	10	51	12.0 SRITSMOON JAR & GrAY SAUD, CONSC & GERVAL		14	
8 =		erator E	J.	70	7.5 B			9,0			10.5			12.05			
		1	SAMPLE	FROM		1		8.3			8%			7,7			
	ME	Drill Rig CE 45.2. Inspector OLEIN LOYD	VE	7.0	6.5 6.3			8.0	8.5	9.0	9.5	0.0	10.5	11.0	11.5	12.0	
	HAC BIT	704 OLEN	DRIVE	FROM	6.0	6.5	3.0	7.5	8.0		0%	9,5	<i>8</i>	2.0	11.0	11.5	
	Buzz	Inspecto	STRATUM	5									2007			12.0	
	Beace B	522	STRA	FROM										- 10,5			
	8	Drill Rig Cle 45.2. Inspecto	PATE	TAKEN	1350			KSept			(15 am)			15Ser			
	Project	Location Drill Rig	CAMBLE	NUMBER	Ŋ			J			7			90			

Project Location Drill Rig SAMPLE NUMBER	BLACK BAUSTE STR. KEN FROM FROM FROM FROM FROM FROM FROM FROM	2 Inspector 02. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.	TO FROM TO 1/2, O 1/2,			E	E DAM Site Site OKEM LOYO Operator Erayle Streuge I Surface El DRIVE SAMPLE TYPE OF SAMPLER 12.0 12.5 12.3 13.5 SPLISPOOY JAR 7 13.0 13.5 13.5 SPLISPOOY JAR 9 14.0 14.5 15.0 SPLISPOOY JAR 9 15.0 15.5 16.5 SPLISPOOY JAR 9 16.0 16.5 16.0 SPLISPOOY JAR 5 16.0 16.5 5 5 5 16.5 SPLISPOOY JAR 5 16.0 16.5 5 5 16.5 SPLISPOOY JAR 5 16.5 16.0 SPLISPOOY JAR 5 16.5 16.5 16.5 JAR 5 16.5 JAR 5 16.5	JAR JAR	4 C 0 0 C 7 0 4 0 0 0 7 1	Date 1956PT 81 Job No. Boring No.55-1 "E !! CLASSIFICATION AND REMARKS BLUE-GRAY, SAUDY-CLAY HED BLUE-GRAY, SAUDY-CLAY HED BLUE-GRAY, SAUDY-CLAY HED BLUE-GRAY, SAUDY-CLAY HED
			17.0	17.0 17.5 17.5 18.0					00 %	

Sheet 3 of 7 Sheets

							∞I	BORING LOG FIELD DATA			
Project	Project Burse Burre DE	CL B	הנות	THE DAH	7			Site			Date 1987 61
Drill R	Drill Rig CE 4522 Inspector OLEN LOVD	725	nspecto	N OCEN	7007		erator 2	Operator FROUK STEWART Surface El	PRT Sur	face E	
SAMPLE		STRATUM	TUM	DR	DRIVE	SAMPLE	PLE	TYPE OF	4	157	
NUMBER	TAKEN	FROM	T0	FROM	10	FROM	70	SAMPLER	ere!	2010	CLASSIFICATION AND REMARKS
13	185007			18.0	18.0 18.5	18.0	19.5	19.5 SRITSPON	JAR	77	BLUG-GERY, SANDY- CLAY HED.
				18.5	18.5 19.0		_ {			0	•
				19.0	19.5					15.	
7/	18501			25.0		25.0	26.5	25.5 25.0 26.5 SPLITSPOOL	JAR	21	12 BULE-Gray, SAUDY-CAY MO
				25.5	25.5 26.0					22	
				26.0	26.0 26.5					23	
15	KSEPT			30.0 SO.5		30,0	34.5	30,0 31,5 SPUTSPOON	IAR	0/	IAR 10 BLUE GRAP, SANDY-CLAY HED.
				30.5	D.5 31.0					22	
				31.0	31.0 31.5					30	
;				1	,	1	2			1	234
3	17.55			3	? 3	25.0	26.2	30.000 35.0 36.2 SMJ5/00A	1	?	שרתפ - לפונה אמומג - רישה
				35.5	35.5 36.0					14	41 W/ 1/2 BASALTHARIN EDDOFTER
			36.2	36,0	6.2 36.0 36.3					50	

Sheet #

	Date 21 Sept 81		Boring No. 22-1	SYGENES ON MOTERIFICATION TO	ļ	BLUE-GRAY CLAY WITH ROCKS MED	BUNG-GRAP WROCKS MED.	,			BASALT ROCK-LOST 1 BLUEGARDY	Mas, Ichay	BASALT BOCK - LOST !!	where Being-copy MED.	BASALT ROCK - LOST 0.5'	wicht Brus.capty Med.	BASALT DOK OVCH BLUE GERY HED.	BASALT ROCK YOUNG BLUKGITHY MED.	
			ırtace i	570	''શ	30	1	33	\$		1		1		-		1	1	_
			7	*****	4	JAR	102				200		200 E		CURE		Coer's Box	ASS. BOX	
BORING LOG FIELD DATA	Site		Operator Fearly Me W. Surface El	TYPE OF	SAMPLER	40.0 40.5 40.0 40.5 SPLITS POON	45.0 46.5 45.0 45.5 SPLITSPOON JAR	ļ			55.0 50.0 54.0 Z-BARRE		55.6 57,1 55,0 56.0 R. BAREEL		57.1 59.0 57.1 58.5 R-BARRET		59.0 60.3 59.0 60,3 7-Bazeer	60.3 61.5 60.3 61.5 R-BARREZ	
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1			erator Z	LE	10	40.5	45.5	46.0	46.5		54.0		56.0		58.5		60,3	517	
		'	o 	SAMPLE	FROM	40.0	45.0	45,5 46.0	46.0 46.5		50.0		55.0		52.1		55.0	60.3	
			9407	/E	10	40.5	46.5				55.0		57.1		59,0		60.3	61.5	
	HOZ	706	nspector Over 10 VD	DRIVE	FROM	40.0	45.0				50.0		55.0		57.1		59.0	60.3	
	HBC SHI	-PH 706	nspector	тим	7.0					47.0									
	BLACE BU			STRATUM	FROM	36.2					49.0								
	360	Location Desustre	Drill Rig CE 1522	DATE	TAKEN	215001	3/507												
	Project	Location	Drill Rig	SAMPLE	NUMBER	17	81				31		2.0		12		77	23	

Sheet S of

	Date 22.5 @PT.81			CLASSIFICATION AND REMARKS	BASALT ROCK - LOST 1,3'	WICLAY BLUE MED.	BASALT ROCK-LOST 0.8'	W/CLAY BLUKMED.	BASALT ROCK - LOST 2, W.	HUD STONE, GRAY STIPE CLAY				Hub STOUT LOST 0.2"	OLOV STIFF CC,	TWD STOUG COST O.G.	Cody Stiesel.	Mudstone Tost 0,4"
		rface E	7	NO OF	_		,		,	10	23	37		1				,
		1	and a	E COM	700F		200E		300g						250	8	340	200
BORING LOG FIELD DATA	Site	Operator Fenus Secusion Surface El	l	SAMPLER	61.5 65.1 62.8 65.1 R-892BMZ.		A-BARREZ		R.BMRET	70.0 71,5 SPLITSPOOD JAR				71.5 73.0 71.7 73.0 BICHED TUBE BORRED	Coro	INCHER IURE	1	78.6 76.2 14, 6 46.2 MICHER IUMBBOARD
901		erator 🔁	LE	TO	1:59		67.3		30.0	71.5			Ĭ	73.0		13.6	,	3
		ි 	SAMPLE	FROM	8.79		65.9 63.3			30.0				7.17	,	15.0		ار الا
		2070	Į.	10	1.50		67.3		70.0 69.3	305	21.0	31.5		73.0	1	74.6		76.2
	AEA P	Inspector Overy Coyo	DRIVE	FROM	61.5		1:59		67.3	700	205	310 71.5		3115		13.0		2%
	7 3	Spector	LUM.	10					70.0									
	x B		STRATUM	FROM						30.0				\top		1		
	Project Berk By	Drill RigCE ys 22	DATE	TAKEN	20 Sept		22.500		235.007	24Seot 70.0				24 Sept		14.567		24564
	Project_	Drill Rig	SAMPLE	NUMBER	77		25	· -	3%	27				28		5	T	8

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Sheet 6 of 7 Shi

	Date 26SEPTRI	Job No.	Boring No. 55-7 "E"	CLASSIFICATION AND REMARKS			HUDGOCK, GRAY STIFF BL	0-112	MUDROCK GRAY SIMPCE		MUDROL GEA! STEF CL		HUDECK, GARY STIFF CL		MUDROCK, GRAP STIFF CL	HUDBOCK, GRAY STIFF CL	Zoct 8,7 634"	1/30 DE 00	71, 3,46, 3,78 (2027)	PWC PIPE ENTH CAP OF BO HOM. PASHED POWLY & 100, CENCOT-WATER GROUT USED	m I MRT Conter 41 Ples T Gar Rus Kinter (1600 From O'A SO' DEFM. Hale CHECKEDW/3/ STEEL ZUST.	Cheet 7 of 7 Sheets
			rface E	25	- 2		1					į		_	_			12		7000	450'	ı
		1	e.7 Su	BRAN	in.	1.	TUB6	×43	7	Š	100		128×		2 S	35		1/10		den	100	
BORING LOG FIELD DATA	Site		Operator Editor STEWALT Surface El	TYPE OF	ĺ		PITCHER TUBETUBE		PITCHER MEG TUBE		87.0 85.0 87.0 Brown Tugo rubs		90,0 92.0 Brainer Tuge Tube		95.0 57.0 Premer FORE MOS	97.5 59.5 99.5 Provereundruge		Ft down Sp. 175 row Delver with 10-16 HAMMER 4/30" DEOP		So Hom. Rus	Vorae Used Fe	
BC			erator Z	LE	2			$\neg \vdash$	\neg		073		0.2		0.53	28.37		ביוויבים		0000	2 Rus	
			1	SAMPLE	FROM		76,2 78.2	1	78.8 80.2 78.2 80.2		85.0		0,00		\$5.0	57.5		g 0.00		DUTH.	mrs	
	1		707م		10		78.E	1	2.0		33.0		1		920	25.5		R/75/		2,00	11/2 11	0
	WITE DAY	TOUE	SEN	DRIVE	FROM		76.2		₹8.6		85.0		90.0 92.0		8.0	23.5		2000		PWG.	reen	0,000
	WITE	_ HU	spector	M 1	70													FFE		4'I.D.	74 / 74	& DOW
	ck B	STRE	u 27	STRATUM	FROM			+	+									(D. K		200	30,00	740
}	BLACK	100g	56.45	DATE	TAKEN		2 48 LETT	+	MSEPT		25 Sept		25.80		792.56	Los Sept		2" 00 M 36"		Hole CASED	1204 50 4400 Oct	FORM A10
	Project	1 oration POWLISTREAM TOK	Drill Rig CE 4522 Inspector OLEN LOYD	_	NUMBER		3/ 2		32		33		34 2		بي ج	3.76		* 2.01		191 **	100	FOR FOR

Sheet Z of Z

			T		-3		آ	<u></u>	·	scarded second	0.0		T_T_T	1 %
	Date 29 SEPT 81			CLASSIFICATION AND REMARKS	BOLL DIE 8 34" TO START DE NINSO	BATTELL GRAY SAND-COARSE	NO SAHPLE, GTAY SAND-COOLSE	NO SAMPLE, GrAY SAUD-COOKSE	A GRAY SAND - COARSE	GCAY SAUD-COOKSE, SAMPLE COMMUNICATION	Gray Spans 1/2 Accor TUBE CONTRAINETED	POCK BIT 83 - WABLE to SAUPLE GRAY ROCKS PAD GITAVEL	ROOK BIT 84- UUABLE 6 SAUDLE GRADLE	Sheet / of Sheets
		Surface	_						Pretire	1	Par			"Il not
FIELD DATA	Site	Operator FRBUK STETURE! Surface El	TYPE OF	SAMPLER	NONE		6" Denvisou	6" DENUISON	"DEDUISON JACTURE	10,0 ("DEUNISON JAN	12.0 ("DENUXSAU JS	1	1	*Deanison Britell Willast
레프		erator E	J.E.	5					8,0	0'01	12.0	NOWE	NOWE	Deanis
		0 Q O	SAMPLE	FROM			NOVE	HONE	61.8	9.0	10.5	7/0	WO	
	DAM	14	VE	7.0	2,0		4.0	0.9	8.0	0'01	0.2/	0140	0 16.0	MAY BE USED
	[] ₁	0	DRIVE	FROM	0.0		2.0	4.0	079	8.0	10.01	12.0	14.0	
	BLACK BUTTE	nspector	TUM	70						10.0	12.0			EDITION OF NOV 1971
	CK Z	722	STRATUM	FROM	0.0	,					0.01	12.0		EDITIO
	1,3	120	DATE	TAKEN	29Sep		79 Sept.	P.Sem	29 Sept	29 Ser.	25 Serre	2958-01 12.0	75.50	819
	Project	Orill Rig	SAMPLE	NUMBER	ı			2	7	7	4	9	34	WES FORM

								5	•			KG.						
	Date 29 Sert 81	Job No.	Boring No. 4/5-1 "F"	SYGENED GIVE MOLEVONE	CLASSIFICATION AND NEWARKS		BLUE CLAY STRETED AT 17.0 MED	Dar Hir 83" - Blue CLOY WIR ROLE HED		BLUE SOUDY CLAY HAD	BLUE SAUDY CLAY- TUBE	BLUE SALOY CLAY-BOYNT-CODSONICE HES	S"THEE BLUE SAUDY CLAY HAD.	Rock BIT	HARD BLUE CLIPPINTH SWALL BOCKS	RAN UNABLE TO SAMPLE	Buye C. AP With JOKS, HED.	
			face E									186	,301	Roc				
			27 Sur				JAR	.		786	1	5"n	2,,5	43%		7	5"71.00	
BORING LOG FIELD DATA	Site		Operator FRAUK STEWART Surface El	TYPE OF	SAMPLER		18.0 6"DENUISON	PACK BIT 8 1/2		20.0 22,0 21.6 22,0 6" bewisold	Cussic Lisas	30,0 32.4 30.1 32,4 5" CORE BARRES 5" 7486	35. 0 37. 4 35.8 37. 4 core 2000.	STARTED REPUIDS WITH 6	40.0 40,5 40.0 40,5 core BARREL	63" Rak B	48.0 49,0 48,1 49.0 500 Bases S	
991 r			erator 🛭	E	10		0.8			22.0	VE	32,4	37.4	Repu	40.5		49.0	
				SAMPLE	FROM		17.5	Z.NOW.		21.6	NONE	30.7	35.8	STED	40.0		1.84	
 	7		CRO7 NEW		10			0		22.0	27.0	32.4	32.4	STR	10,5	480	49,0	
	DAM	106	NEN	DRIVE	FROM	_	0'81 0'91	0000		0'02	25.0 27.0	30,0	0 %	35.0	40.0	40.5	48.0	
	Sutte	EPH	spector	3	7.0	17.0		6	2						40.0			
	CK Z	U STR	522 In	STRATUM	FROM		130		0.81									
	378	Dow	05 45	DATE	TAKEN		29 Sept 170	8	+-	/oct	1007	10cT	1,80		1001	-	201	
	Project BLACK Butte	Location	Drill Rig CE 4522 Inspector	_	NUMBER		80	0		/ 0/	/	2/		Τ	*/		75/	

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Sheet 2 of 3 Sheets

Sheets WES JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Hole CASSED W/4"ID, PYC PIPE WITH CAP ON JATTOM, PLENED TO 100'; CEMENT - WHERE GRENT USED FRANCS' to 100' depth, Hole CASSED W/6 1/6" STEEL INST. to 100'.

| PART CEMENT WIPART CAE! PLUS WORRY USED From O to STO DEPTH. Note Checked W/6 1/6" STEEL INST. to 100'. In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Llopis, Jose L.

In situ seismic investigation of Black Butte Dam / by Jose L. Llopis and Ronald E. Wahl (Geotechnical Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss.: The Station; Springfield, Va.: available from NTIS 1982

Va.; available from NTTS, 1982.

79 p. in various pagings: ill.; 27 cm. -(Miscellaneous paper; GL-82-18)

Cover title.

"December 1982." Final report.

"Prepared for U.S. Army Engineer District, Sacramento."

1. Black Butte Dam (Calif.) 2. Seismic waves.
3. Seismology. I. Wahl, Ronald. E. II. United States.
Army. Corps of Engineers. Sacramento District. III. U.S.
Army Engineer Waterways Experiment Station. Geotechnical

Llopis, Jose L.

In situ seismic investigation of Black Butte Dam : ... 1982.

(Card 2)

Laboratory. IV. Title V. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station); GL-82-18.
TA7.W34m no.GL-82-18

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